METHODOLOGY FOR MONITORING WILDLIFE DIVERSITY IN B.C. FORESTS

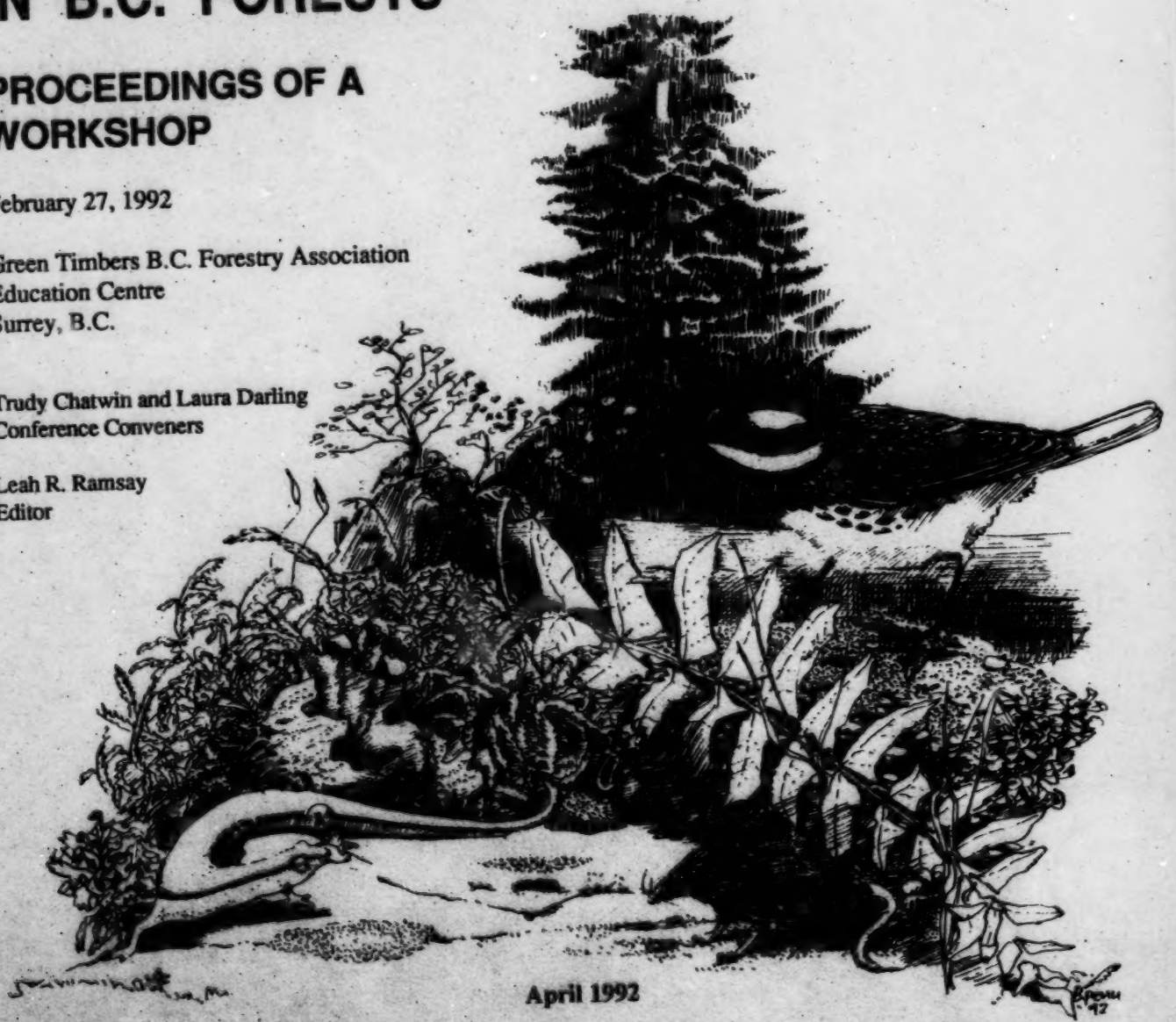
PROCEEDINGS OF A WORKSHOP

February 27, 1992

Green Timbers B.C. Forestry Association
Education Centre
Surrey, B.C.

Trudy Chatwin and Laura Darling
Conference Conveners

Leah R. Ramsay
Editor



April 1992

Province of British Columbia
Ministry of Environment,
Lands and Parks

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WILDLIFE BRANCH

BC Environment

April 1992

Canadian Cataloguing in Publication Data
Main entry under title:
Methodology for monitoring wildlife diversity in B.C. forests

Includes bibliographical references.
ISBN 0-7726-1579-9

1. Wildlife watching - British Columbia - Methodology. 2. Wildlife research - British Columbia - Methodology. 3. Forest fauna - British Columbia. I. Ramsay, Leah R. II. BC Environment. Wildlife Branch.

QL60.M47 1992 333.95'411'09711 C92-092228-7

PREFACE

The impact of forest practices on wildlife diversity and the potential losses to biodiversity through forest management are research topics of immediate concern throughout British Columbia. In 1991, the Research and Development Section of the Wildlife Branch, Ministry of Environment, Lands and Parks began to coordinate several projects researching the effect of various forest practices on biodiversity, and we began a research project to: " Monitor changes in Wildlife Diversity during Silviculture Systems, Hardwood and Vegetation Management trials funded by the Forest Renewal Program". As we began to formulate a study design for research, appropriate sampling methodology became an issue. Other researchers communicated similar concerns as overall biodiversity research was a relatively new research area in British Columbia. We felt that a workshop would open communication regarding different methodologies for researching wildlife in our forests, and would also bring together experts and experience to give better coordination to wildlife-forestry studies in British Columbia. The workshop was designed to provide a forum for wildlife researchers, wildlife managers, and others interested in monitoring wildlife under various forest management scenarios in British Columbia.

The goals of the workshop were:

- to foster communication and information sharing regarding methods and analysis for monitoring wildlife diversity in forested and managed forest ecosystems;

- to help ensure that the results of wildlife forestry research being conducted in B.C. will be comparable, defendable, and valuable. Wildlife forestry research should increase the understanding of wildlife and forest habitat relationships, and ultimately lead to forest management that integrates goals of wildlife diversity and sustainability.

This document is a compilation of speakers' notes, papers, and abstracts from the workshop; "**Methodology for Monitoring Wildlife in British Columbia Forests**" held on February 27, 1992, at the British Columbia Forestry Association Education Centre, Surrey, B.C. The papers presented herein represent the opinions of the authors, and were not subject to scientific review or editorial comment. References are included at the end of each paper to give greater scope to the topics. These proceedings are intended to help wildlife forestry researchers and managers in their challenging endeavours in British Columbia.

As a first step to opening communication between the many divergent people interested in biodiversity, the workshop was very successful. Participants included university students and professors, Fish and Wildlife managers and biologists, Forest Science Ecologists and researchers, consultants, Parks biologists, and environmental group biologists. Questionnaire results indicate that the workshop was well received, and participants overwhelmingly supported having a future workshop with a similar biodiversity research topic focus.

Trudy Chatwin and Laura Darling
Conference Conveners

ACKNOWLEDGEMENTS

Thanks to:

The Resource Inventory Committee of the Ministry of Forests and the Wildlife Branch of the Ministry of Environment, Lands and Parks provided the financial support to prepare and publish this document.

The staff at the B.C. Forestry Education Centre graciously shared their facilities and provided assistance. Myke Chutter assisted with many arrangements including transportation and organization of video equipment. John Kelson video-taped the conference. Briony Penn and Gail Harcombe made artistic contributions to the agenda, and Briony Penn did the cover illustration for this document. Leah Ramsey and Gail Harcombe laid-out and edited the papers.

Tony Hamilton, Andrew Harcombe, Don Eastman, and Brian Nyberg provided support, encouragement and ideas at all stages of the workshop through to the publishing of these proceedings.

We thank especially the speakers for their well prepared presentations and proceedings summary notes. The speakers are to be commended for keeping to the topics assigned and the rigorous time limits imposed upon them! (Although we all wanted more time for discussion!).

Lastly, we thank the participants who held on to the end in a warm room on a beautiful, sunny February day!

VIDEOTAPES

Videotapes of the workshop are available from Trudy Chatwin, c/o Wildlife Branch, BC Environment, 780 Blanshard St., Victoria, B.C. V8V 1X5. Phone (604) 387-9756

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STUDY DESIGNS FOR BIODIVERSITY MONITORING AND RESEARCH

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This talk examines study designs for biodiversity monitoring and research in terms of five basic questions. First, I ask what we mean by biodiversity in the first place; good design requires that we look carefully at how biologists and the public have been confused about this term. Second, I point out that measured biodiversity depends on the spatial scale of study; different ecosystems have different diversity versus scale "signatures" that imply different monitoring and experimental unit requirements. Third, I question whether existing information management systems are appropriate to help us see the large scale, long term dynamics of biodiversity, and suggest that there is a big need for better information management systems. Fourth, I question whether monitoring of existing forest management practices alone can tell us how to manage for biodiversity, and suggest that very large scale experiments involving manipulation of cut block sizes are needed. Finally, I ask what institutional arrangements will be needed to carry out such large experiments.

What Is Meant by Biodiversity?

Unfortunately, ecologists mean something very different by diversity than do many environmentalists. What the greenies are mainly talking about is the richness of specialist species associated with old-growth forests; they do not like to include successional "weed species" in the calculation of biodiversity. Let us call a spade a spade, and proceed with honesty about value-laden versus scientific definitions. I will be talking about scientific definitions.

How Does Apparent Biodiversity Depend on Scale of Measurement?

One reason that ecological scientists have largely stopped studying diversity is the realization that diversity measures depend strongly on the size of study site used.

Even tropical rain forests are not particularly diverse on small (10-100 m, one tree) scales.

We can measure how diversity depends on measurement scale by using species-area or diversity-scale curves (Figure 1). Any forest ecosystem has a characteristic curve or "signature" that depends on local competitive interactions, size and complexity of topographic features, and impacts of management (Figure 2).

The species-area signature is likely to have breaks at spatial scales where major habitat features (edges of clear-cuts, slope/aspect changes etc.) appear. Species added at scales larger than these features are new local habitat specialists and also broad-ranging species that depend on edges or multiple habitats. Wildlife biologists have long known that many species actually benefit from the habitat "fragmentation" that concerns some ecologists and environmentalists; a key issue is whether forest management can be used toactually improve biodiversity (Figure 3).

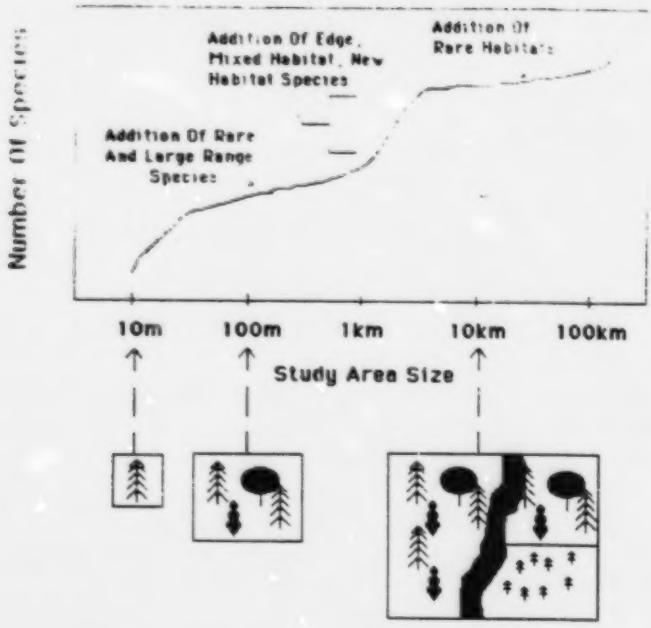

Figure 1: Diversity - Scale Signature. The study area size will affect the number of species found. As open cuts across topographical boundaries there will be an increase in the number of species due to new habitats, species that use more than one habitat and edge species.

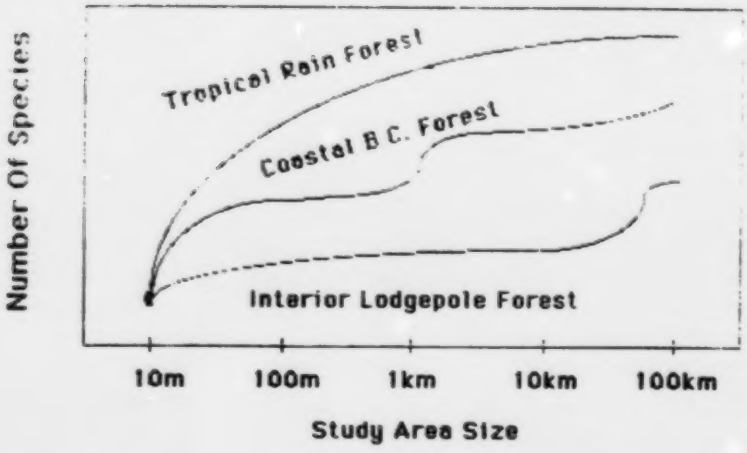

Figure 2: Different forest types will give different diversity - scale signatures.

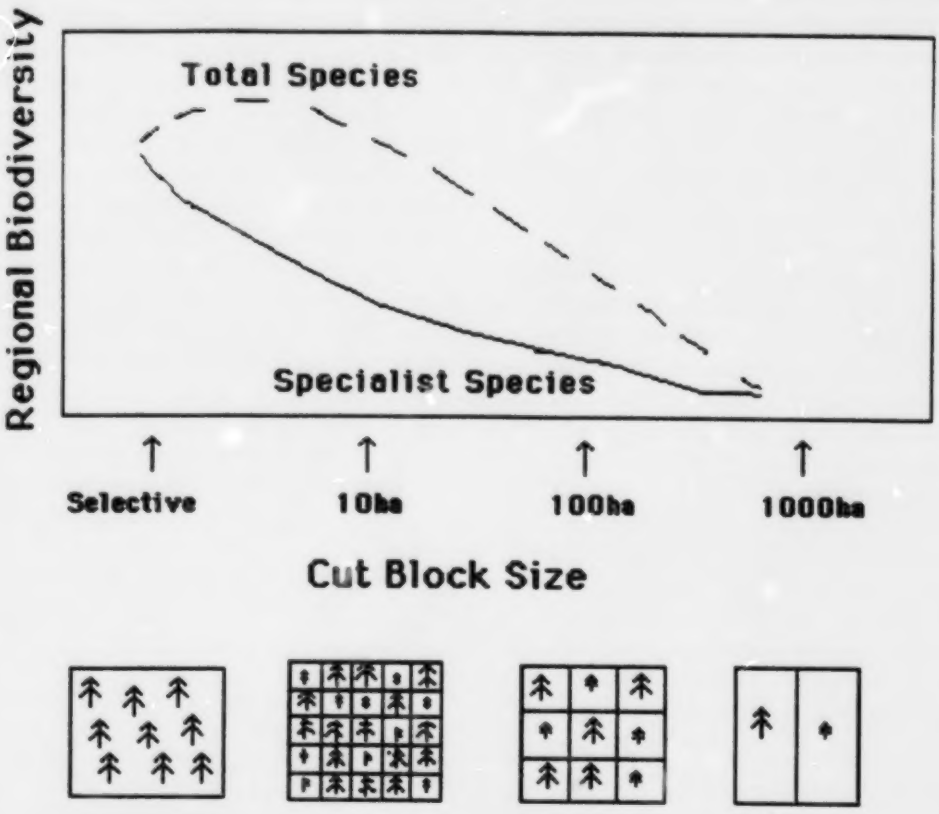

Figure 3: Can management increase biodiversity? The 10 ha cutblock sizes yield the most diversity.

How Can We Visualize the Large-Scale Dynamics of Biodiversity Over Time?

We are progressively reshaping the spatial mosaic of forest habitats in B.C., and this process is not going to stop. There is a real need to step back from thinking about impacts on a site-specific basis, and to learn how to visualize and think about this reshaping on large scales.

I use two computer programs to demonstrate techniques to visualize long-term, large-scale change. One program has been used to develop new water management strategies for one of the world's largest wetlands, the Florida Everglades. The second is being developed to study how big game populations and hunting pressure are shifting over the mosaic of game management units in B.C.

What Experimental Designs Should Be Used to Study Impacts of Forest Management on Biodiversity?

Simple monitoring of diversity over existing forest management regimes is not likely to uncover opportunities for improved management. In particular, there is a great need to systematically study how biodiversity on regional spatial scales varies with forest cut-block size. The impacts of other forest management variables (silviculture, etc.) can be studied with relative ease in local areas.

Reliable experiments for management have four key features: (1) contrasting management treatments for comparison of performance; (2) replication to insure that apparent treatment differences are not accidents due to study site effects; (3) interspersion of experimental units over large

regions, to insure that measured differences are broadly applicable; and (4) a carefully selected set of response measurements (rather than the false pretence that "all" relevant factors will be measured).

The hallmarks for future management experiments should be more sites, bigger sites, and innovative monitoring technologies. We have had nothing but trouble in the past with unreplicated and pre- vs post-treatment comparisons, as witness the continuing debate about how to interpret measured responses in places like Carnation Creek. I recommend very strongly against even considering such weak comparisons. We have been forced into them in the past by scientists demanding that financial resources for monitoring be concentrated on detailed measurements ("trying to measure everything" can only be done on a few sites). It is intellectually dishonest to pretend that detailed data are "necessary" to interpret responses of interest to management; the real need is to show whether there are in fact robust responses in the first place. If using more experimental areas means measuring much less on each area, then what we should be concentrat-

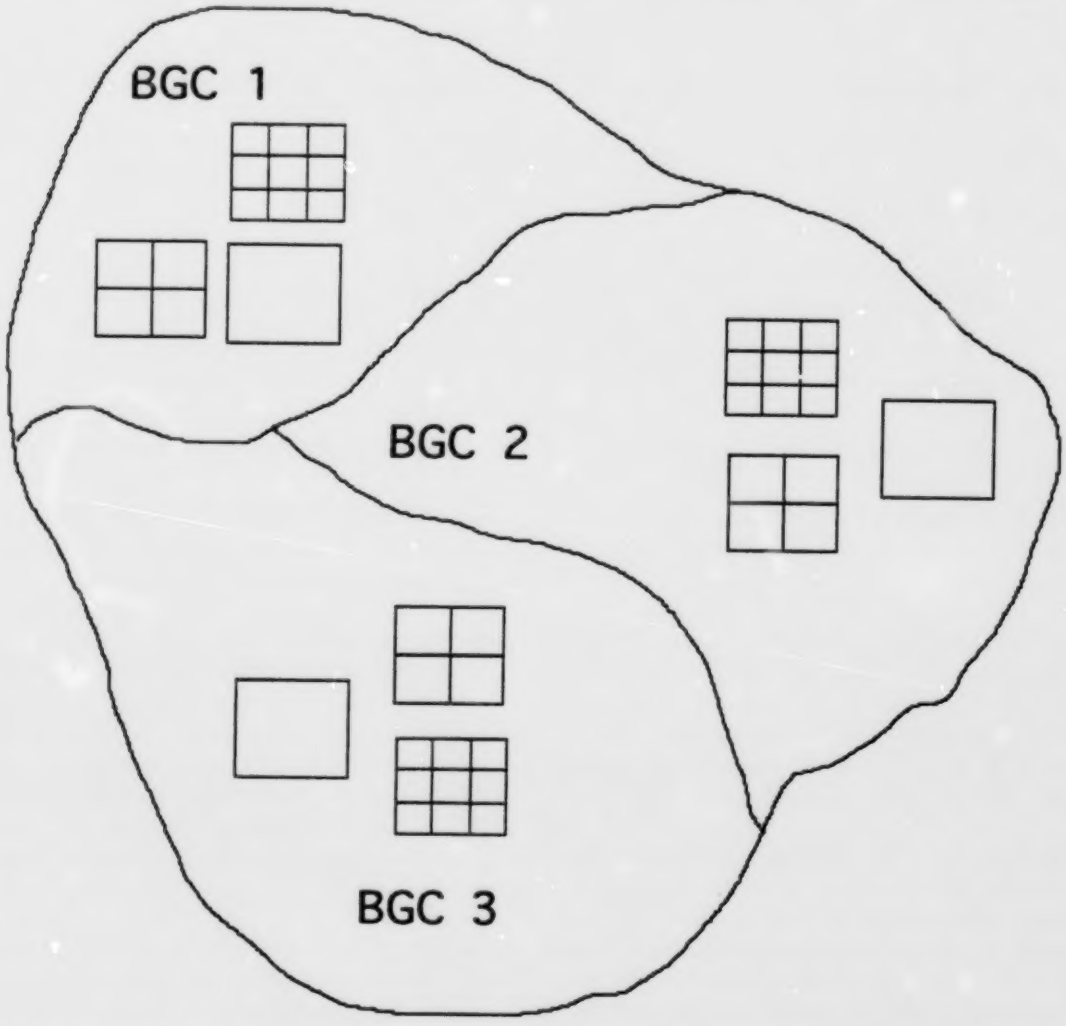

Figure 4: A simple experimental design using broad spatial coverage and blocking to assess the effects of cut block size on biodiversity. BGC refers to biogeoclimatic zone.

ing on is how to priorize the most important measurements and how to do innovative monitoring more cheaply by using devices such as satellite imagery and tracking.

Figure 4 shows a simple design for assessing the effects of cut block size on biodiversity. This design illustrates the idea of spreading experimental units broadly over the region of interest (a set of units in each biogeoclimatic zone, BGC). It also uses blocking of units within each BGC to provide cleaner (less site-to-site variability) comparisons among treatments within each BGC block.

What Institutional Arrangements Are Needed for Successful Field Experiments to Study Biodiversity at Large Scales?

The development of large scale management experiments is not just a matter of defining experimental treatments, units, and monitoring requirements. Much of the cost of doing such experiments is in conducting the manipulations in the first place, and presumably it is the forest industry that will bear these costs. Also, resource users (forest industry, hunters and fishermen, trappers, recreational guides) cover a lot more area than biologists can ever hope to by themselves, and these users are potentially a major source of monitoring information if they can be co-opted to gather that information more carefully and scientifically.

So the development of successful large experiments will require much attention to the economic and social questions of how to provide incentives for the forest industry and other users to cooperate in treatment implementation and monitoring. There are many simple ways to provide economic incentives for cooperation in setting up treatment regimes, via stumpage and user fee adjustments and direct public subsidies. The real challenge will be to find innovative, practical, and scientifically defensible ways to get more cooperation in monitoring. Current institutional arrangements do encourage some limited cooperation in monitoring, but largely through simplistic and annoying devices like harvest reporting and questionnaires.

FOCUS SPECIES FOR MANAGEMENT AND RESEARCH AND MONITORING OF WILDLIFE DIVERSITY IN B.C. FORESTS

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INTRODUCTION

Focus, or selected, species are commonly used to simplify the task of managing and monitoring wildlife diversity. Several approaches to the process of selecting focus species are discussed. All of the approaches discussed have substantial conceptual overlap but differ in emphasis. A distinction is made between focus species for forest land management planning and focus species for monitoring and research.

EXISTING APPROACHES

Featured Species Approach

In the featured species approach, the habitat requirements of one species guide the coordination of timber and wildlife management **on any one site in the forest**. Many species can be featured over the entire management area by featuring different species in different areas. This approach originated in the southeastern USA in the early 1970s and is now the explicit management policy in Ontario and the implicit management policy in many other provinces. This approach has the advantage of being simple to implement from a management and monitoring point of view. Its main disadvantage is that the conceptual basis is weak, i.e., why choose the species to be featured. It is acknowledged by all that looking after one species may look after many others but **certainly** not all others.

Management Indicator Species Approach

In the management indicator species (M.I.S.) approach, consideration is given to the habitat needs of a group of species whose populations are believed to indicate the effects of management activities. M.I.S. are normally selected from 4 groups:

1. endangered and threatened;
2. featured game/commercial and "interesting";
3. those with habitat needs that make them sensitive; or
4. those that indicate trends in the population/habitat of other species.

This is the legally mandated approach to maintenance of biodiversity on National Forests in the USA under the National Forest Management Act (1976). Most emphasis in the USA has been on selection of species from the fourth criteria (ecological indicators).

There is a substantial body of U.S. literature criticizing the M.I.S. Main criticisms fall into 4 main categories:

1. Because the species chosen as indicators are often well understood, managing for their habitat requirements will likely lead to very specific prescriptions that will enhance the habitat for the indicator species but not for the "indicated" species;
2. There is no clear or objective method for selecting suitable indicator species nor for selecting the number of indicator species required;
3. Extrapolating habitat quality or population response for one species to habitat

quality or population response for another species is tenuous at best. Therefore, monitoring the habitat or population response of the indicator species will not necessarily give any information about the "indicated" species;

4. Indicator species are frequently resilient to environmental changes because they are chosen from species that are wide-ranging, so that the concept can be applied over large areas.

PROPOSED APPROACHES

Looking at Everything

A "Diversity Approach" has been suggested in which explicit consideration of particular species is avoided. Rather, the assumption is made that the goal of maintaining wildlife diversity can be met by a Forest Land Management Process that provides a diverse set of habitat conditions through consideration of habitat features alone. The intent of this approach is to provide a "diversity of diversity"; i.e., diversity would be provided at different spatial scales. For example, some stands would have a diversity of age classes, there would be a diversity of stands of different age classes and there would be a diversity of landscapes some with uniform age classes and some with diverse age classes.

This approach has several proponents in the literature on biodiversity and biological conservation and its goal (maintaining wildlife diversity) is included in U.S. legislation and most Canadian policy statements.

There are several problems with this approach:

1. there are no *a priori* methods of determining which habitat features should be managed for;

2. there is no conceptually correct distribution of habitat diversity, i.e., the objectives for habitat diversity, particularly at the among stand and among landscape level, must be stated in terms of the inhabitants of the area;

3. monitoring the implementation of the approach requires that some meaningful and measurable indices of habitat diversity be developed. Monitoring the efficacy of the approach requires that populations of all species be monitored.

Species Guilds For Management Purposes

A guild is a group of species that exploit the same class of environmental resources in a similar way. I suggest that species guilds can be used to overcome some of the problems of the "Diversity Approach". Specifically, guilds might be useful in determining the distribution of habitat features that should be managed for.

Guilds are artificial constructs of the investigator for the purposes of analysis in addressing certain questions. In the past, guilds have been applied, primarily for research purposes, to taxonomically restricted groups of vertebrates (usually birds) and have been defined in terms of similarities in resource use patterns (e.g. insectivorous birds may be divided into foliage gleaners, bark borers etc.).

I believe that the following factors must be included in the guild definition:

1. all species, not just terrestrial vertebrates must be included in the guilding process;

2. all aspects of a species life history must be included in the definition of the guild to which it belongs, not just its resources use patterns;

3. guilds must be defined in terms of the spatial scale of habitat applicable to their members;

4. temporal patterns in resource use and temporal scale appropriate to the species must be included; and

5. guild definition must include reliance on, and interaction with, other guilds.

It is possible, and even likely, that well-defined guilds will include only one species. If this is the case then guild theory needs to be developed using a goal-oriented, holistic approach rather than a explanation-oriented, reductionistic approach.

The use of guilds for monitoring environmental management plans has many detractors in the literature, and rightly so. As artificial constructs, guilds are not entities that can be monitored. Either all species in each guild would have to monitored or "indicators" of the guild would have to be selected, resulting in the same problems as the management indicator approach. Szaro (1986) indicates that "guilds may **merely** be a tool helping us to determine which habitat factors are important in management decisions". Therefore, having made management decisions based on guilds, we need a method of selecting species to monitor those decisions. I provide some suggestions in the next section.

Selection of Species for Monitoring the Impacts of Forest Management Activities

I offer the following suggestions for selection of species for monitoring the efficacy of Forest Land Management Plans for maintaining appropriate habitat diversity:

1. the most important factor is that the species must be sensitive to alteration of the habitat feature under consideration. That is, a population level response must be anticipated in response to changes in the habitat feature;

2. at least one species per habitat feature should be chosen;

3. the species should be correct for the scale of the habitat alteration being studied. For example, salamanders would be inappropriate for studying the effects of the spatial arrangement of forest stands;

4. the species must be appropriate for the study design. For example, if the research topic is "does decreasing patch size affect the species that will occur in the patches?" then species that vary in home range size should be chosen; whereas for the question "will species persist in small patches that vary in their degree of isolation?" then species that vary in their dispersal characteristics should be chosen;

5. it must be possible (economical) to detect the population response of interest (e.g. presence/absence, population change, reproductive fitness). Considerations of sampling methodology aside, the distribution, density and resilience of the species must be considered. One should not automatically (if ever) choose rare species because of the effort required to detect changes in their populations.

CONCLUSION

The Issue of Objectives Regarding Biodiversity

I believe that a primary cause of the difficulty and confusion regarding methods for managing and monitoring "biodiversity" in B.C. results from unclear and potentially inappropriate objectives.

There are at least two potentially "right" objectives regarding biodiversity:

1. maintenance of all native forms of "wildlife" in their current geographical distributions; and

2. maintenance of all natural ecosystems in forms that function without substantial human intervention.

While these objectives are not mutually exclusive or diametrically opposed, they do have differ-

ences in emphasis, and managers and researchers would act differently depending on which objective was chosen. The bottom line is that until we have decisions about clear and achievable objectives from our leaders (political and/or bureaucratic), the process of managing and monitoring biodiversity will be bogged down in technical details.

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VOUCHER SPECIMENS: AN ESSENTIAL COMPONENT OF BIOLOGICAL SURVEYS

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"Voucher specimens" are representative specimens that are collected in biological field surveys and research, and that are preserved to permit independent verification of results and to allow further study. The term "specimen" covers diverse materials such as photographs and tape recordings, but usually refers to more traditional preparations like skins, skulls, pressed plants, or dead animals in preserving fluids.

Many kinds of animals and plants that are of interest in environmental impact studies or biological surveys can only be reliably identified when they have been preserved as specimens. **Without such voucher specimens it is impossible to independently verify an investigator's claims, it is impossible to re-evaluate the species present in a sample in light of changing knowledge and taxonomic revisions, and it is**

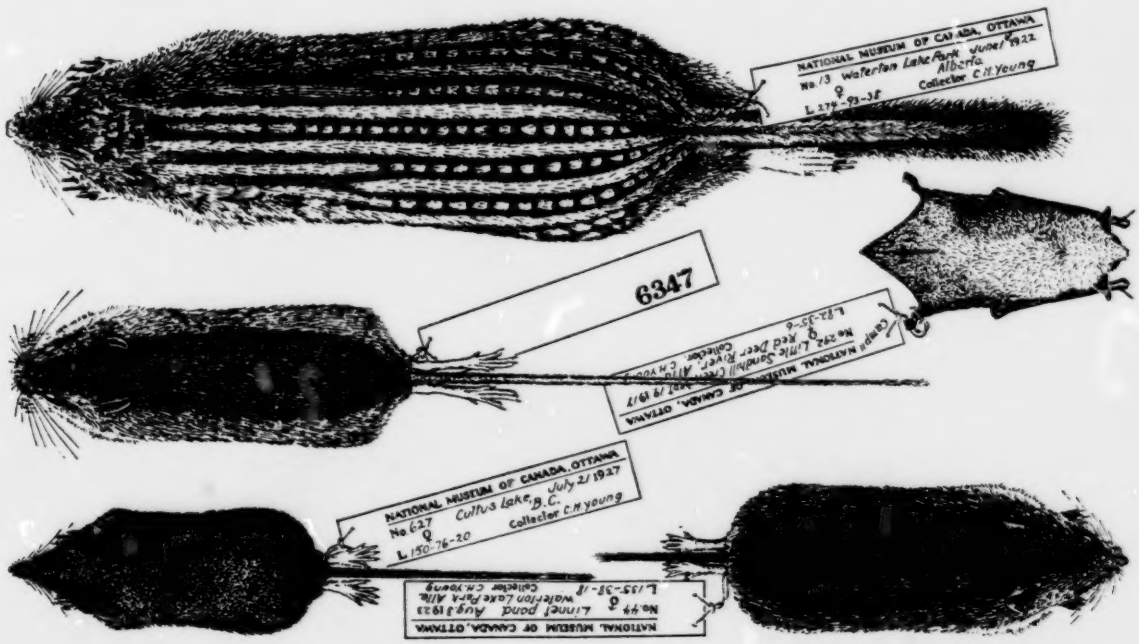
NATIONAL MUSEUM OF CANADA, OTTAWA
No. 13 ♀ Waterton Lake Park Alberta
Collector C.H. Young
6347
NATIONAL MUSEUM OF CANADA, OTTAWA
No. 627 ♀ Cultus Lake, B.C. July 2/1927
Collector C.H. young

Figure 1. Traditional study skins of mammals. Many modern study skins have limbs missing from one side, because their bones are preserved along with the skeleton; bats usually have the single wing spread.

impossible to reliably make historical comparisons or trace ecological changes over time due to environmental effects such as pollution or climate change. Voucher specimens are also invaluable for related studies, such as on seasonal occurrence, taxonomy, distribution, and life history. Aside from these scientific reasons for preserving voucher specimens, invetigators have an ethical obligation to fully use plants and animals that they collect, particularly for uncommon or long-lived species, or in areas that become irrevocably altered by human activity.

Voucher specimens take various forms and are accompanied by various kinds of information, according to what is needed to identify them, by a study's purposes, and by changing knowledge. For example, some small mammals may be frozen or preserved in fluid (e.g., alcohol); others may be prepared in the field as skulls, skins or skeletons; yet others may have blood or tissue samples saved for genetical analysis. Standard information includes date, locality, elevation, habitat, and field reference number, but data on weather, time of day, soil characteristics, etc., may be important in some studies. Because the ways in which specimens are preserved are set by a study's purposes, it is important to establish detailed protocols when a study is planned.

Responsibilities for properly preserving and storing voucher specimens are shared among agencies that are supporting the field work, museums that will be receiving and storing the specimens obtained through field work, and people who actually do the field work and collecting. Granting and sponsoring agencies should stipulate that voucher material be collected in biological surveys, and that it be deposited in appropriate museums. Costs of collecting, preserving, and storing specimens (e.g., film, alcohol, jars, storage cabinets, labour) should normally be built into project budgets. Responsibilities of museums are to provide curatorial, legal and technical advice on collecting, preserving, documenting and depositing voucher specimens. Arrangements with museums for training field investigators and for accepting voucher specimens should be planned early in a project, so that training needs can be met and logistical considerations can be addressed. Museums must maintain voucher specimens in good condition and make them readily accessible. Finally, museums should provide advice to investigators on conventions for formally referring to specimens in reports and publications. Field investigators and collectors are responsible for properly sampling, preserving and documenting specimens, and for ensuring that biologically and statistically

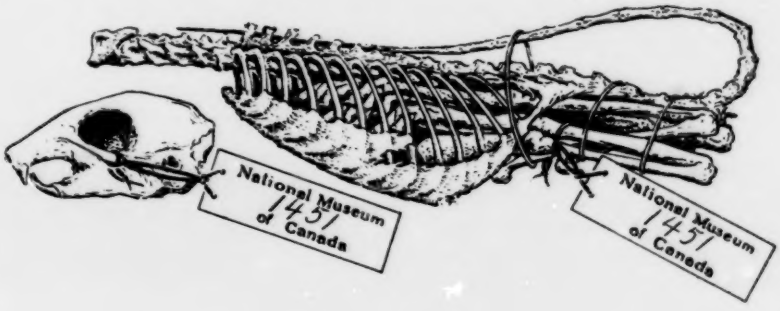

Figure 2. Dried ligamentary skeleton of a small mammal specimen, as prepared in the field. Note the tag with field number.

satisfactory samples of collections are placed in a museum after a project is completed. As well, investigators should cross-reference voucher specimens in all reports and publications.

Small forest mammals are a diverse and ecologically important group that illustrate the importance of voucher specimens. They include species that are difficult or impossible to identify except as scientific specimens, including many bats, shrews, and mice. In addition, some forms have been recognized as biologically distinct species only recently. One example is the Deer Mouse (*Peromyscus maniculatus*) and Columbian Mouse (*P. oreas*), which were confirmed to be different species only in 1988; Dusky and Vagrant Shrews (*Sorex monticolus* and *S. vagrans*) were confirmed as distinct from one another in 1977. These pairs of species coexist over broad areas and may even be taken in the same trapline. Distinguishing them in the field is difficult or impossible: examination of voucher specimens is essential to confirm species identity. Regrettably, no specimens of small mammals were preserved

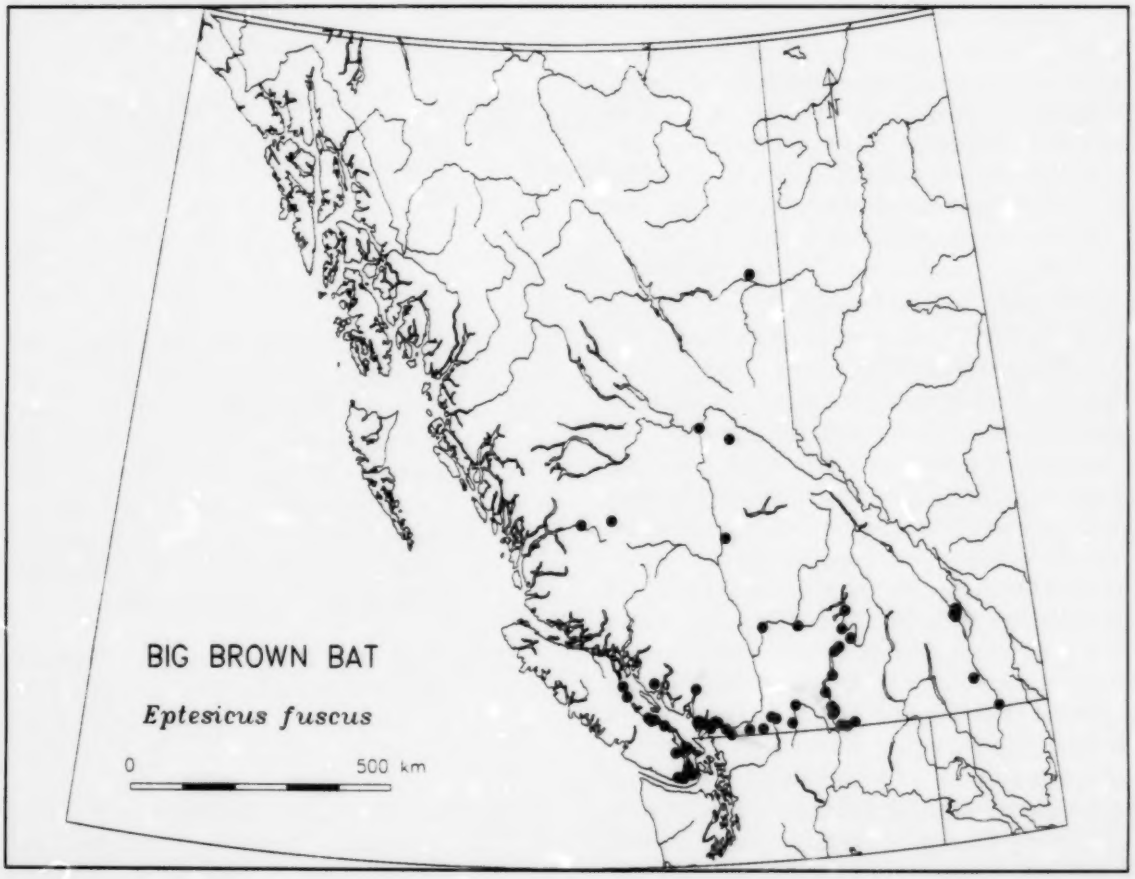

Figure 3. Geographic distribution of the Big Brown Bat in British Columbia, based on known museum specimens. Most species of bats can only be identified by experts, and certain species can only be identified if specimen material like skulls and skins is available. (From Nagorsen and Brigham 1992.)

in some important surveys in the past, so it is now impossible to know which species were actually sampled, or in what proportions or habitats. Obviously our knowledge of the species' geographic distributions has also been limited by the absence of voucher specimens from such studies.

It is unethical to kill individuals of rare species in order to obtain voucher specimens. For such species, acceptable voucher specimens may be individuals that are found dead, animal parts or (in some cases) photographs. Existing museum collections are an essential resource for documenting the occurrence of rare forms. Consider the Keen's Long-eared Myotis (*Myotis keenii*), a bat species that inhabits coastal old-growth forests and that may be threatened in British Columbia. Based on re-examination of all known museum specimens, there appear to be only three records of this species from the mainland: other, previously published records, were of the commoner Western Long-eared Myotis (*Myotis evotis*), and were based on misidentified specimens!

Our society values biological diversity (or "biodiversity"). Museums have crucial roles to play in documenting biodiversity. Their research should stress systematics (including zoogeography and taxonomy), with particular attention to organisms that are poorly known, that vary geographically, or that are of conservation or management concern. Examples in British Columbia are: distinctive island populations, such as the Ermine (*Mustela erminea haidarum*) and Hairy Woodpecker (*Picoides villosus picoideus*) on the Queen Charlotte Islands; species with curiously disjunct distributions, such as the ecologically different populations of alpine and dry-interior Brewer's Sparrow (*Spizella breweri*); and groups like bats that are of management concern yet whose distributions and ecological requirements are poorly known. Museums should publish handbooks, range maps, identification keys, distributional lists, manuals, and other "user-friendly" materials; they should contribute to field training and to workshops on identification and taxonomy; they should set standards for collecting, preparing and documenting specimens; they should provide expertise and assistance in identifying problematic specimens or taxonomic groups; and they should act as repositories for voucher specimens.

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*All these references are in the Library of the Royal B.C. Museum and may be examined there or obtained through inter-library loan. Contact Ms. F. Verspoor, Librarian, Royal B.C. Museum, Victoria, B.C. V8V 1X4 (phone 387-2916; FAX

BIOPHYSICAL HABITAT MAPPING FOR ANIMALS

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HABITAT CLASSIFICATION

Ecological classification and mapping done by the Wildlife Branch of the British Columbia Ministry of Environment, Lands and Parks is oriented toward identifying habitat for selected wild animals, such as elk, moose, mountain sheep, caribou, mountain goat, black-tailed deer, white-tailed deer or grizzly bears. The emphasis on other wild animals is developing as requests for this information increase. In fact, in the South Okanagan area, a project is in progress that deals with fifty-five, mostly non-game, species.

The two main goals of biophysical mapping are:

1. to provide a framework to assess the suitability and capability of the land surface for supporting wild animals (Demarchi *et al.* 1983, Fuhr and Demarchi 1990); and

2. to provide a framework for improving animal habitat. The biophysical classification describes and maps land areas that have relatively homogeneous climatic, physical (including soil) and vegetative characteristics of importance to animals.

The Biophysical Classification of the British Columbia Ministry of Environment, Lands and Parks is a classification which unites physical and biological elements - soil, landforms, climate, vegetation, and water to form a coordinated entity (Demarchi and Lea 1989a).

Beyond the need to inventory terrestrial ecosystems for wildlife many species also utilize water bodies for part or all of their habitat requirements. While some species such as whales and dolphins are fully aquatic, other species such as seals, sea-lions, beavers, muskrats, waterfowl, gulls, turtles and frogs require both aquatic and terrestrial habitats for various stages of their life-cycles; some species such as mink, bald eagle, osprey and grizzly bear are more dependant on fish as prey species which in turn require water bodies in order to survive. Therefore, classifications of wetlands, streams, lakes, shore-zones and oceanic areas have been included in this classification as a component of terrestrial vertebrate habitat identification requirements.

The units derived express what is theorized to be ecologically important in the landscape for animals. The Biophysical Classification framework has evolved to fulfill four requirements:

1. the classification system is to be based as much as possible on relatively permanent land or water and climate features and to the extent possible, provide compatibility and consistency with existing classification systems;

2. the classification system is hierarchical, through aggregation and disaggregation it can provide decision-making information at several administrative or geographic levels;

3. the classification is based on ecological principles and measurable or readily inferable features of the land, each unit of the classification is identifiable by the on-the-ground examination;

4. the system is mappable, whether by conventional cartography or computer-operated information systems.

The hierarchy used for biophysical mapping includes **Ecoregions, Biogeoclimatic Units** (zonation) and **Biophysical Habitat Classes.**

1. Ecoregions are broad climatic units for the province, based on climatic processes, physiography, and broad animal and plant distribution (Demarchi 1988).

2. Biogeoclimatic Units, as mapped by the British Columbia Ministry of Forests, provide a climatic framework for mapping within each Ecoregion, as well as a framework for mapping plant community distribution (Pojar *et al.* 1987). In Biophysical mapping we usually use Biogeoclimatic Subzones.

3. Biophysical Habitat Classes, the lowest level of our mapping hierarchy, are relatively homogeneous units with respect to bedrock geology, surficial materials, soils, climate, topography, successional trends of vegetation and potential animal use. These units are divided into successional stages or range condition classes for mapping.

Predictability of vegetation parameters is important for determining what areas can be improved for forage and cover for animals. We describe the vegetation, and potential forage and cover characteristics for animals, for all successional stages. Most of our interpretations for animals are done from these units. Our maps are presented at various scales, with 1:50 000 and 1:20 000 scales being most common, but also including 1:250 000 for more remote areas and 1:5 000 for estuaries.

Field crews usually consist of a pedologist, who interprets bedrock geology, surficial materials and soils, a vegetation ecologist who interprets climatic parameters, succession and stand characteristics; a biologist who interprets current animal use and potential occurrence. All are responsible for developing habitat management interpretations. Our greatest successes began when scientists from all three disciplines were present during field trips, agreed to the location of each plot and then simultaneously sampled the site. Interpretations and unit delineation were also better served when the same air photos were used.

MAPPING METHODS

Mapping of ecological units is based on soils, topography, bedrock geology, vegetation (including present and potential successional stages) and animal use (Figure 1). Habitat Classes (lowest level ecological units) are mapped within a framework of Ecoregions and Biogeoclimatic Zonation Units.

The types of units we map are based on the animals we determine to be a priority for the area. Due to mapping for non-game species, we have ended up mapping various habitats such as cliff features for species such as Canyon Wrens, White-throated Swifts and various bat species, as well as mapping particular soils that are used by fossorial creatures such as Pocket Mice, Burrowing Owls, and snakes.

Unlike much of the mapping going on in the Pacific Northwest, which is dominantly based on vegetation and specifically climax vegetation, our mapping is strongly based on permanent physical features that determine the whole range of successional stages, including present vegetation that occurs on a particular site; our main goals in sampling are to determine the relationships between site characteristics vegetation and use by animals, including determining what various successional vegetation will occur on a site - thus we can map, starting with the physical base of surficial materials, soils and topography and be able to extrapolate known vegetation relationships to map ecological units of meaning to animals. This mapping is like detailed range site mapping and could be quite valuable for range management, as the polygons are soil and topography derived.

We map the present successional stage or range condition class for each unit and describe all potential successional vegetation in a legend -

thus management opportunities for each unit can be assessed. Once the habitat units are mapped, we rate each unit for its current suitability and capability to support each animal species. Suitability determines what animals can be supported under the present vegetation on a particular unit while capability indicates what animals can be supported under the best successional stage for that species.

We are presently using computer drafting for our work and generate colour maps to show suitability and capability maps. The mapping can be used to help integration of planning with other resource agencies as it identifies our priority areas; it can be used for acquisition, protection of habitat and enhancement.

MAIN USES OF ANIMAL HABITAT INVENTORY MAPPING INFORMATION

Habitat mapping provides a base:

- to assess the current suitability of the land to support a particular animal species (potential for a species with the present vegetation);
- to assess capability of the land to support a particular animal species (potential for a species with the best successional stages);
- to identify enhancement and other management opportunities.

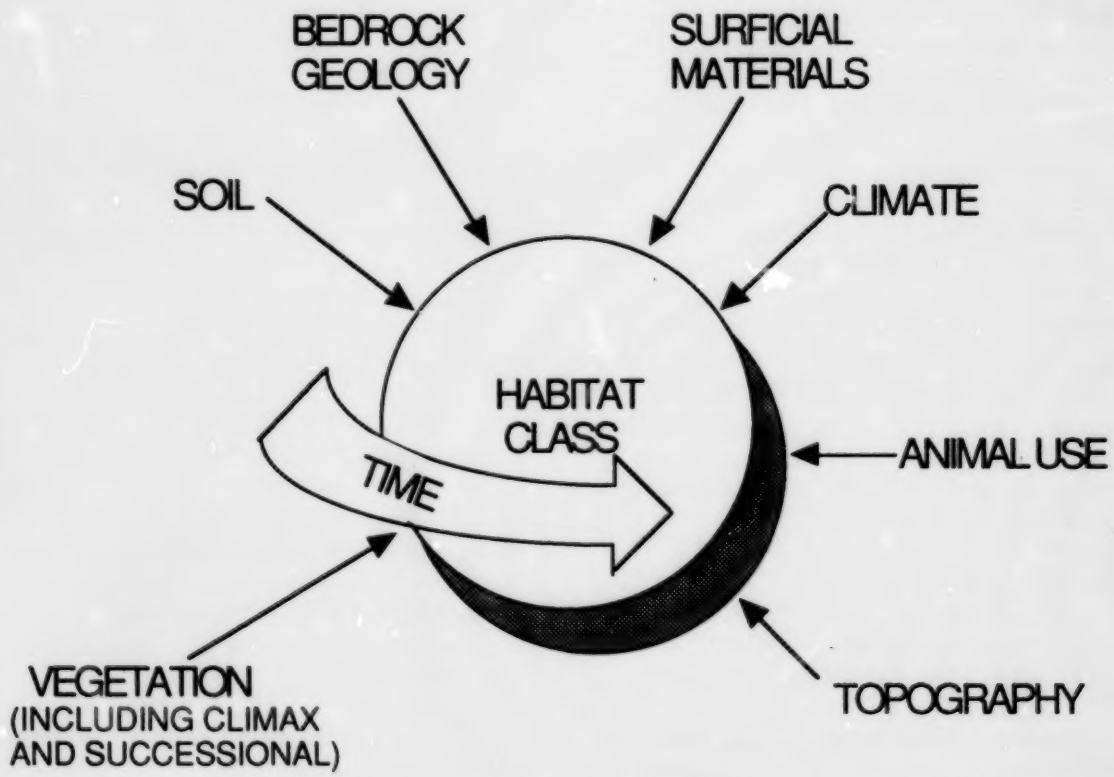

Figure 1. Parameters that are used to define habitat class.

FACTORS CONSIDERED IN MAPPING ANIMAL HABITAT

1. Climate:

- seasonal precipitation (including snow depth)
- seasonal temperature

These factors have an effect on plant productivity, plant composition, season of use and the ease of movement in the winter. Biogeoclimatic zonation is used to get an idea of climate in an area.

2. Topography:

- degree of slope
- aspect
- position in the landscape
- elevation

These factors will have an effect on soil moisture, plant productivity, plant composition and winter snow depths (easier movement on warm aspects).

3. Soil/Terrain/Bedrock:

- soil/material texture
- soil moisture
- soil depth
- nutrient availability
- litter layers (depth, kind)

Most of the above represent permanent land features that do not change with harvesting, forest fires and succession, therefore they are our initial mapping units. They will have an effect on plant composition, forage productivity and ease of burrowing, as well as sensitivities for management and tree productivity.

4. Vegetation:

- plant community
- plant composition
- plant productivity (forage species)
- stand age
- plant potential (potential successional stages; primary or secondary succession)
- stand structure (physiognomy and density (canopy closure of tree, shrub or herb layers)
- stand height (at least or shrubs)
- specific elements (snags, coarse woody debris)
- potential for fruit production

The vegetation determines what animal species can occur and how well they will do.

UTILITY OF HABITAT CLASSIFICATION FOR BIODIVERSITY RESEARCH

- ability to compare similar or different habitats in project design;
- indicates those factors that should be considered in research so that variation in habitat value is accounted for; and provides the
- ability to extrapolate research information to similar habitats.

VARIATION BETWEEN HABITAT UNITS MAPPED THE SAME

- value of adjacent polygons
- small areas of higher values that cannot be mapped
- physiognomy (stand appearance):
  - deciduous/mixed/coniferous
  - canopy closure
- specific habitat elements:
  - snags
- coarse woody debris
- these factors are often unit specific and may be difficult to extrapolate from the broad Habitat Class
- differences in these factors may cause large differences in habitat value.

PROCESS OF MAPPING

- field sampling
- development of classification:
  - ecological units based on site and vegeta tion characteristics
- mapping of soil/terrain/topography units on air photos
- mapping of Ecological classification:

- Ecoregion classification
- Biogeoclimatic zonation (subzones)
- Habitat Classes
- Successional Stages/Range Condition/ Vegetation Phases

- mapping of animal suitability or capability or interpretive maps.

COMPARISON TO BIOGEOCLIMATIC SYSTEM

- more emphasis on physical factors:
  - soil/terrain/topography used for mapping
  - these are permanent landscape features
  - Biogeoclimatic is a vegetation-based classification
- where phases described the two systems are very close
- mapping of successional stages
- classification and mapping of non-forested units
  - emphasis on those habitats important for species of concern

OTHER USES FOR HABITAT MAPPING

- site sensitivities (soil/topography information)
- tree species selection for planting
- other silviculture prescriptions
- tree species capability, site index, growth and yield models
- cattle capability

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PROCEDURES FOR HABITAT MONITORING

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In British Columbia, activities that result in changes to natural ecosystems have not been consistently monitored under a common system of data collection and analysis. The provincial ministries of Environment and Forests, recognizing a need to work cooperatively on questions of resource allocation, developed "Procedures for Habitat Monitoring" (Habitat Monitoring Committee 1990) to monitor activities that affect wildlife habitat and rangelands.

The goal of this manual is to provide a standard system for the monitoring of changes to natural ecosystems that result from operational activities:

> ***To enhance our ability to make informed decisions on resource use questions that pertain to range and wildlife habitat management.***

The manual documents procedures for monitoring and assessing all conventional habitat enhancement techniques. Building on standardized approaches and definitions for the collection of ecological data, the objectives of the manual are:

1. to standardize a set of operational-level procedures for the documentation and sampling of pre-treatment conditions, the treatment activity and the post-treatment response of the site and vegetation to a prescribed treatment;

2. to ensure that habitat project goals and objectives are adequately and measurably defined;

3. to provide standard data needs for each treatment;

4. to develop a reliable, uniform data base for habitat management monitoring;

5. to facilitate and encourage the transfer of information among resource users to improve communication and integration of resource objectives.

Our ability to achieve integrated resource management objectives, and greater accountability in the cost-effectiveness of operational programs, depends on building knowledge and improving communications. Treatments should be tailored to suit different ecological conditions. Good resource stewardship must address both the primary program objectives and secondary effects on non-target resources. This can be accomplished through the use of these procedures, and the companion data system that houses the information collected.

The intended users are technical and professional field staff, and their contractors. The emphasis is on monitoring of operational activities rather than research level monitoring. The procedures integrate existing data collection methodologies within the two ministries as much as possible, as the intent is to complement rather than replace existing methodologies.

These procedures are being applied to representative samples of operational activities to help refine techniques within an ecological framework, and to provide information on treatment effectiveness and their impact on other resources and resource users.

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Habitat Monitoring Committee. 1990. Procedures for environmental monitoring in range and wildlife habitat management. Draft edition version 4.1. B.C. Ministry of Environment, Lands and Parks and B.C. Ministry of Forests, Victoria, B.C. 196pp.

Copies of this report may be obtained, depending upon supply, from:

Wildlife Branch
British Columbia Ministry of Environment,
Lands and Parks
780 Blanshard Street
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or

Integrated Resources Branch
British Columbia Ministry of Forests
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MEASUREMENT OF HABITAT ELEMENTS AT THE STAND LEVEL

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Biodiversity at the stand level (alpha diversity for many terrestrial vertebrates) is influenced by composition and structure of the stand. Stand features which contribute to structure include coarse woody debris, wildlife trees, and vegetative strata. Comparison of results between studies and study areas necessitates the standardization of data collection and reporting methods for these habitat elements. The following outlines data collection and analysis methods for describing the above habitat elements at the stand level.

Coarse Woody Debris

Coarse woody debris (CWD) as used in this document refers to dead and downed woody material and does not include wildlife trees (aka snags). There are a number of characteristics of CWD which should be considered when describing it at the stand level. These include volume, size and number of pieces, decay characteristics, and vertical structure. There may be instances where it will be important to document distribution.The following method has been adapted from methods for assessing fuel loading for prescribed fire as described in Van Wagner (1968), Brown (1974), Brown and Roussopoulos (1974), McRae (1979), and Trowbridge *et al.* (1987). This methodology is designed as an efficient means of assessing the amount of dead and downed woody material in a particular habitat unit, cutblock, etc. This volume can be calculated for any size/decay/height classes that are recorded.

The technique involves recording the diameter, height, and decay class of all pieces of downed woody material along a given transect at the point at which the transect crosses the piece. As long as actual diameters are recorded, volume can be estimated on for any diameter classes. If pieces are recorded by size class only the investigator is limited to describing CWD in these size classes. Vertical structure can be described by measuring, for each piece, the distance from the top of the material to the ground and the distance from the bottom of the material to the ground. If important for the study a simple index of layering of material could be developed and recorded for each piece.

Maser *et al.* (1979) defined 5 decay classes for logs in Douglas-fir forests based on rigidity, bark characteristics and degree of rot in the interior of the log (Figure 1). They may, however, require some modification for different ecological conditions. Decay characteristics and processes in logs in the Ponderosa Pine biogeoclimatic zone may be quite different than those of logs in the Interior Cedar Hemlock zone. In addition decay charac-

Figure 1. Log decomposition classes (from Maser *et al.* 1979).

teristics of logs after fire may be very different than those of unburned logs and will most likely require some modifications to the classification.

The technique has three assumptions:

1) the pieces are relatively cylindrical. The presence of taper probably introduces a negligible error;

2) all pieces are horizontal. However, the vertical angle can be quite large before the error is serious;

3) the pieces are randomly oriented. This may be a problem in cutblocks where material has been skidded to one landing and is mostly oriented in that direction.

The formula for calculating volume is:

$$V = \frac{\pi^2 \Sigma d^2}{8L} \qquad 1$$

where V is the volume in cubic metres/square metre;
d is the diameter of each piece;
L is the length of the sample line (transect).

In order to eliminate or reduce the problems associated with assumption 3 above, transects may be defined as a triangle with sides 30 m in length (Trowbridge *et al.* 1987). The triangle is centered on plot centre as much as possible. A random bearing is used to locate the first side of the triangle and the other two sides are located at 60° to it. This also helps ensure that the entire transect is located within the habitat type being assessed. In the case of aberrations (such as plots done on old skid roads covered in regenerating conifers) the transects may be a straight line.

A number of rules apply to measuring pieces (See Figure 2):

1) Record the diameter and height of every piece of wood the transect intersects;

2) If the line crosses the end of a piece, tally the piece only if the transect line crosses the piece's central axis;

3) If the transect line passes exactly through the end of the piece's central axis, record every second such piece;

4) If the transect line coincides with the pieces central axis, do not tally;

5) If the transect crosses a piece twice, tally at both points.

The diameter of the piece should be measured perpendicular to the log's central axis at the point where the transect crosses the central axis.

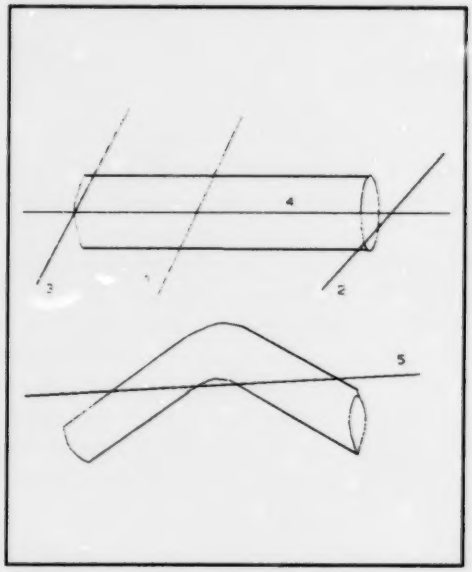

Figure 2. Log tallying rules.

Wildlife Trees

A revised wildlife tree classification system (Manning, pers. comm.) now allows consistent assessment of stands for trees and snags. In this system, each stem is given a class from 1 to 9 depending on its relative health and rate of decay (Figure 3). Investigators should be aware that this

system is still evolving and they should make contact with the Wildlife Tree Committee for updates.

Prism-based variable radius cruise plots, commonly used in forest inventory, can be used to easily assess basal areas and stocking. See Luttmerding *et al.* (1990) (Chapter 5) for a discussion of conducting variable radius cruise plots. Bull *et al.* (1990) discuss the use of variable radius cruise plots to estimate snag densities. Wensel *et al.* (1980) provides a discussion on the selection of basal area factor in variable radius cruise sampling. The investigator will need to decide on an individual study basis the appropriate strategy for selection of basal area factor.

For each stem the following data should be recorded:

1) species;

2) DBH - the investigator may impose a minimum size limit;

3) canopy position - Luttmerding *et al.* (1990) (Chapter 4) describe 4 strata into which stems can be classified (A0 - A3);

4) tree classification.(Figure 3). Wildlife tree classification (after Wildlife Tree Committee 1992).

Optional data that may be of interest include height of tree classes 3 through 7, and the age of one of the A2 strata trees.

Stocking is calculated by the following formula:

$$SPH = \frac{1}{\frac{((d \times PRF)^2)\pi}{10000}} \qquad 2$$

where SPH is stems per hectare;
PRF is plot radius factor;
d is tree diameter.

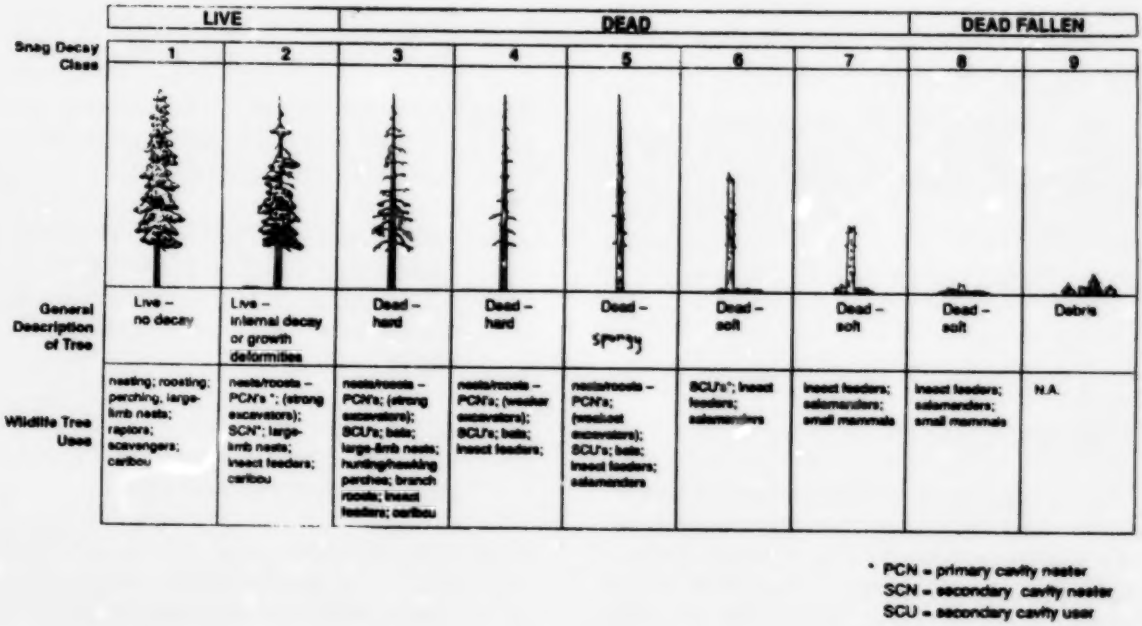

Figure 3. Wildlife tree classification (after Wildlife Tree Committee 1992).

Formula (2) gives a stocking density for each tree diameter measured. Stocking density, by diameter size class, can be calculated by multiplying SPH by the number of stems in the plot in the size class of interest.

Plot radius factor (PRF) is calculated by the following formula:

$$PRF = \frac{0.5}{\sqrt{BAF}} \qquad 3$$

where BAF is the basal area factor of the prism used.

Basal area is calculated by the following formula:

$$BA = (BAF)(N) \qquad 4$$

where BA is basal area in square metres per hectare;
BAF is basal area factor;
N is number of trees tallied in plot.

Vegetative Strata

Ocular percent cover estimates or percent cover classes should be recorded for each of the following vegetative strata at a minimum:

1) coniferous trees (A - coniferous)
2) deciduous trees (A - deciduous)
3) tall shrubs (B1)
4) low shrubs (B2)
5) herbs (C)
6) mosses (D)
7) non-vegetated.

The investigator may want to subdivide these further into more categories (for example the A - coniferous into A0 - A3 coniferous, or into species). Optional data may include distribution class, phenology and strata height (See Luttmerding *et al* (1990) Chapter 4 for details).

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WILDLIFE POPULATIONS
MONITORING CHANGES IN POPULATION CHARACTERISTICS: WHAT SHOULD WE MEASURE?

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INTRODUCTION

Roger Green (1979) proposed that applied environmental studies be classified into baseline, monitoring or impact studies. For the purposes of this presentation, I define a *baseline* study as one in which data are collected and analyzed for the purpose of defining the present state of a wildlife population. An *impact* study is one whose purpose is to determine whether a specified impact causes a change in the population, and, if it does, to describe the nature of that change. A *monitoring* study has the purpose of detecting a demographic change in the population from the present state. The demographic changes that I have been asked to discuss include absolute abundance (or density), relative abundance, and demographic vigor.

Specifically, I have been asked to address the question of what should we measure in a population study, e.g. when should we be content to measure presence/absence as opposed to absolute abundance? Obviously, the choice will depend on the objectives of the study, what kind of information is necessary, and the costs of obtaining the information. In virtually all studies, tradeoffs must be made between the desired type and reliability of information, and the cost of obtaining it. Absolute density is more costly and difficult to measure than relative abundance. Fortunately, only a small number of studies (e.g. sustained-yield harvesting, population viability analysis) demand estimates of population size or its absolute density. The majority of monitoring studies can probably be tackled with the help of indices of density. Occasionally, other demographic data (e.g. birth/death rates) may provide additional useful information.

Much effort has gone into the development of methods for estimating population characteristics of animals over the last 15-to-20 years. There are now a number of excellent books on this subject (Seber 1973, Caughley 1977, Davis 1982, Krebs 1989) as well as numerous good review papers (Davis and Winstead 1980, Sen 1982, Sen 1983, Miller, 1984, Seber 1986, Kie 1988). Thus, the biologist need not carry the details of all these methods in his head. However, he or she should concentrate on becoming familiar with the range of methods available and have a rough idea of which methods are appropriate to particular situations. Fig. 1 is a simple flow diagram showing one sequence of decisions that leads to the selection of an appropriate census method. The diagram, although useful, is highly generalized and does not consider methods for a particular species in a specific habitat. Nor does it consider logistical problems, or the relative costs associated with the technique. A more flexible approach might be to develop an expert system where the user could select the most appropriate census method, subject to the conditions and constraints of the study (White *et al.* 1985).

Of equal concern to choosing the appropriate census methodology are associated questions regarding accuracy, precision, frequency and resolution (Gill *et al.* 1983). Accuracy and precision describe the statistical reliability of the estimate. The reliability levels of statistics used in monitoring should depend on at least three factors: (1) the decision risk, i.e. the "cost" and likelihood of being wrong in the projected effect; (2) the natural variation in the parameters expected value of perfect information is highest (Fig. 2).

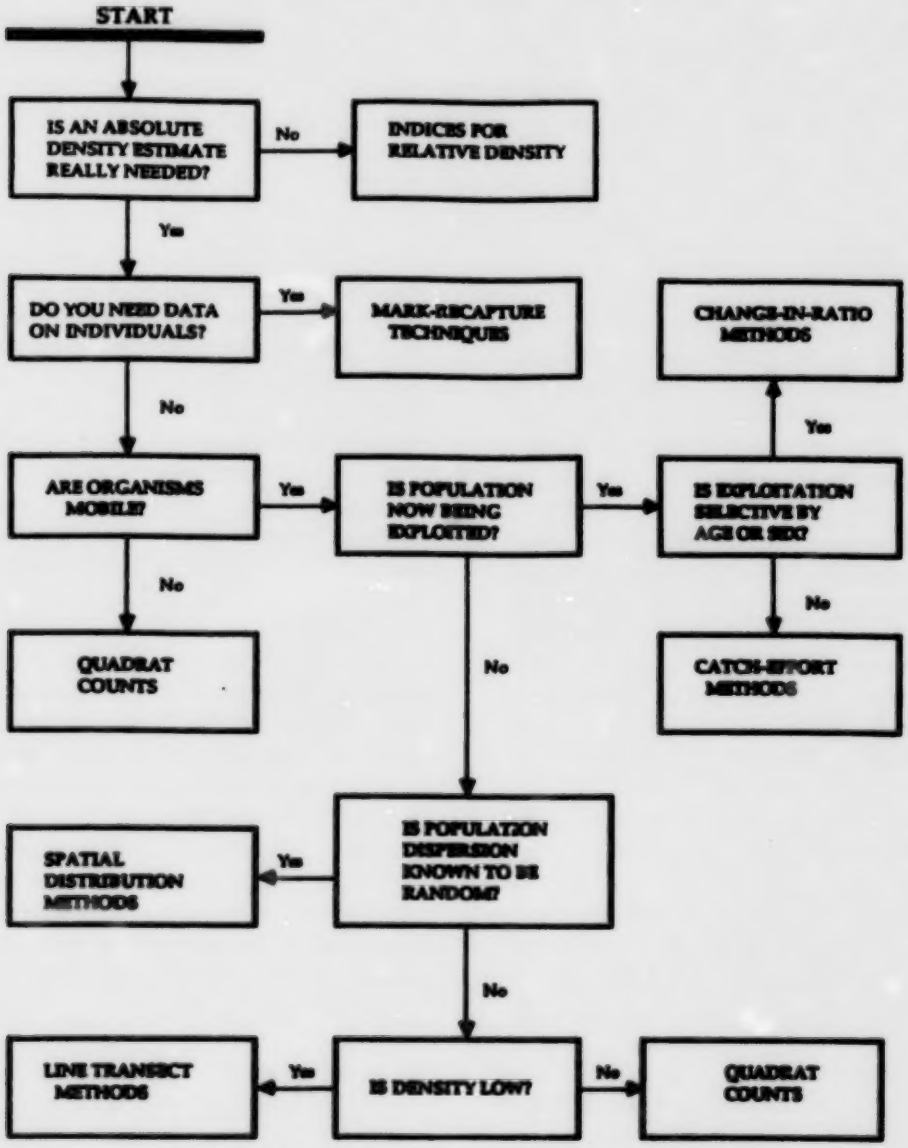

Figure 1. Sequence of decisions by which a technique for estimating abundance can be chosen (from Krebs 1989).

Resolution refers to the degree or extent to which we want samples to apply, e.g. will the data apply to deer within a biophysical habitat unit, an ecosection, or an ecoregion? Frequency refers to how often the census is repeated. In small mammal populations, where turnover rates are rapid, it is necessary to census more frequently than large mammals with longer turnover rates.or characteristics to be measured; and (3) the technology and resources (i.e. people, time and money) available to measure the key parameters (Salwasser *et al.* 1983). Generally, we will want the greatest statistical reliability when the value of perfect information is highest (Fig. 2). Resolution refers to the degree or extent to which we want samples to apply, e.g. will the data apply to deer within a biophysical habitat unit, an ecosection, or an ecoregion? Frequency refers to how often the census is repeated. In small mammal populations, where turnover rates are rapid, it is necessary to census more frequently than in large mammal populations with longer turnover rates.

ABSOLUTE ABUNDANCE

Given that most problems associated with population studies can be resolved by using indices of relative abundance, it might appear that there is little need to discuss absolute abundance survey methods at this workshop. However, there are several reasons why these methods are still appropriate. First of all, indices are often based on animal sign. The density of animal signs is sampled in exactly the same way as the density of animals. Secondly, many attempts to estimate absolute abundance by counting animals are confounded by visibility bias, and in reality, only provide an estimate of relative abundance. And finally, monitoring studies often require an estimate of the population's rate of change. Many indices do not have a direct relationship with actual density, and can not be used to calculate this parameter.

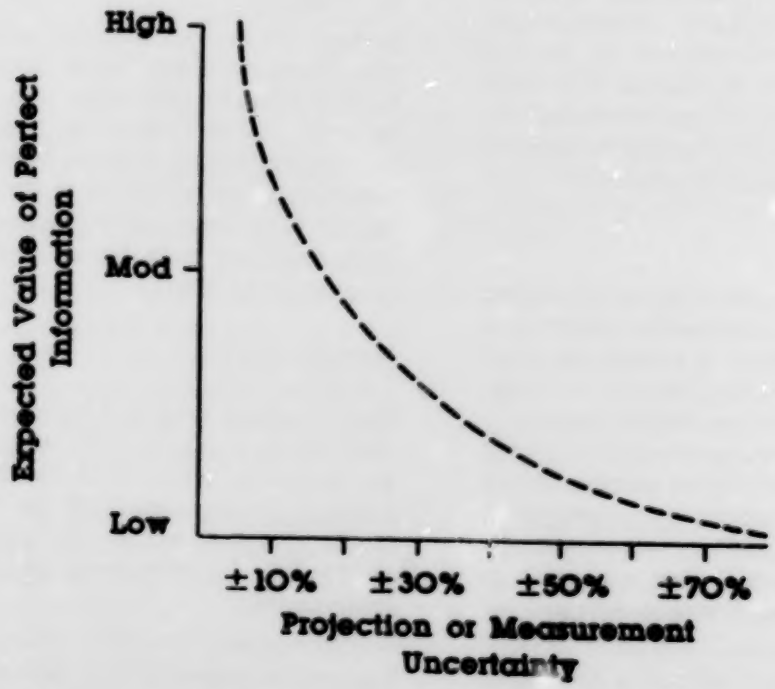

Figure 2. The general relationship between decision risk and the corresponding need for reliability in monitoring statistics (from Salwasser *et al.* 1983).

If the decision is made to use an absolute abundance survey method, the investigator should first consider whether he or she is surveying part of, or an entire, population. When a discrete population is being censused, estimates of absolute size aremost appropriate. If the population does not have distinct boundaries, or the boundaries are unknown, density rather than size is the biologically real measure of abundance (Caughley 1977). Estimates of absolute abundance may be made directly from guesses, total counts, or sampled counts; and indirectly by mark-recapture or exploiting the population through hunting and trapping.

Guesses

I suppose the Wildlife Branch has got to be the leading expert in this "inventory technique". Notwithstanding that a guess is guess, there may be circumstances where a biologist who is thoroughly familiar with a species in a given area might make a realistic guess at the number of animals living there. These circumstances usually involve harvested species where auxillary information is available from harvest/effort statistics; discussions with resident hunters, trappers and guides; and qualitative impressions from aerial and ground surveys. These "guess-estimates" are of little value in themselves but may be useful as cross-checks on an objective estimate.

Total Counts

A count of the total number of animals inhabiting a study area is sometimes feasible when the area is small and the animals are conspicuous. Censuses of this kind are often attempted for endangered and/or threatened species that occupy very specific habitats. The major advantage of total or complete counts is that they are not plagued with sampling errors. However, even conspicuous animals are often missed. Thus, without some independent estimate of visibility bias, total counts are better treated as indices or 'minimal estimates'.

Sampled Counts

Most population estimates are based on sampling procedures. One need only look at recent issues of the *Journal of Wildlife Management* to appreciate this fact. There are several good reasons for this:

1. Sampled counts require less work than total counts;
2. They greatly reduce the chance of double counting;
3. The population is less disturbed by the census;
4. They provide estimates of statistical precision and accuracy.

Stratified random sampling is the most common. Sampling units may be quadrats, circular plots, transects or irregular-shaped polygons. Their use in aerial surveys has been greatly improved by a number of recent developments that correct for visibility bias, i.e. animals missed on the sampling units by the observers (Pollock and Kendall 1987).

Line transect methods have also received a considerable amount of attention, and are particularly suited to ground surveys where animal densities are low (Burnham *et al.* 1980). A disadvantage has been that the more elaborate and robust models require extensive calculations. However, there are now PC-based computer programs available which make these methods much more attractive (Anderson *et al.* 1991).

Mark-Recapture

There is a large amount of literature concerned with mark-recapture techniques. General reviews are provided by Seber (1973), Caughley (1977), Otis *et al.* (1978), Begon (1979) and White *et al.* (1982). Most mark-recapture analyses can be run on IBM-PC compatible computers (Rexstad and Burnham 1991).

Despite the plethora of designs and analyses, all mark-recapture experiments have the same basic format. A sample of animals is captured, marked and released again. The properties of this identifiable sample are then used to estimate the properties of the population as a whole. A number of parameters can be estimated including age-specific fecundity rates, age-specific mortality rates, size of the population, rate of immigration or emigration, and rate of change (Caughley 1977).

Mark-recapture has not received a great deal of attention by wildlife biologists involved management-level studies. Part of this is simply due to the large costs associated with capturing and recapturing animals. However, a number of improvements, particularly those that adopt biotelemetry methodology (Eberhardt 1990, White and Garrott 1990), may result in more use of this technique in the near future.

Exploited Population Techniques

Where a population is being exploited through harvesting or trapping, information provided by the harvest (sex and age composition, total kill) and effort can be used to provide population estimates. These catch-effort methods have received a considerable amount of attention by fisheries biologists (Ricker 1975). We are currently looking at a number of applications to ungulates in B.C. (Dupont 1983, Deriso *et al.* 1985, Novak *et al.* 1991). One particularly promising method combines annual recruitment survey data with observed natural mortality rates to estimate absolute numbers (Allen 1966). Cohort or virtual population analysis may also hold promise for heavily harvested ungulate populations (Fryxell *et al.* 1988). Some data sets are now getting large enough to make these methods possible.

Change-in-ratio methods are another example of a population exploitation technique that may be used to estimate absolute abundance (Paulik and Robson 1969). These methods view a population as composed of two different types of organisms such as males and females, or adults and young. If the harvest is directed primarily towards one type, then the differential change in the ratios of the two types of organisms can be used to calculate a population estimate. Eberhardt (1982) described a more general condition where the population size is estimated from index data collected before and after removal of a known number of individuals. The main problem with these methods is that changes in animal behaviour are often associated with harvesting. If the animals do not have the same probability of being sampled before and after the removal, a fundamental assumption of these models is violated. A new procedure has been proposed for estimating population size when there is unequal catchability (Pollock *et al.* 1985). This procedure operates by having two periods of removal with only one type removed during the first period (e.g. bucks during a male-only deer season) and another type (does during an antlerless-only deer season) in the second period.

RELATIVE ABUNDANCE

As noted previously, many questions regarding animal abundance may be answered with indices of relative abundance. Catch per unit effort, faeces per square meter, density of territorial male birds, or the number of deer observed per km of road are all examples of indices that reveal something about a population's density. Indices may be used to compare one population with another. More typically they are used to monitor numerical changes in a single population over a series of years.

Despite the appeal of indices, I see several major limitations to their use. Perhaps the biggest single disadvantage of indices is that their accuracy depends on strict standardization of the conditions under which they were measured. This is often out of the biologist's control.

Another limitation is that an index is assumed to be linearly related to absolute density although we rarely know this for a fact. Ideally, we would like the relationship between absolute density and the index to be that of a linear regression through the origin (Fig. 3, type Aa). However, other relationships may exist. Type Ab is also linear but does

not pass through the origin. Type C represents a non-linear positive regression. Both type Ab and C may be quite common relationships between absolute densities and indices. Relationships such as type D, where an index value implies 2 different densities, can not be used to even rank densities. Only type Aa can be used to calculate the population's rate of change. However, if the question is "Are densities greater in habitat a than in habitat b", then either types Ab, B or C are usually adequate.

Thirdly, indices are often used because absolute density estimates are considered to be too difficult or costly. The implicit assumption is that the data lacking the quality and quantity needed for population estimation can at least be used for trend monitoring. However, observed trends themselves may be misleading, if they are based on indices that are highly variable. Harris (1986) discusses this problem in detail, and indicates that trend counts based on indices of high variability (i.e. large coefficient of variation) will require multiple counts for acceptable precision. This requires either conducting replicate counts each year, or calculating trends only after a sufficiently long period of time. Neither one of these options may be suitable to the investigator.

Prevalence or Frequency

Perhaps the simplest index of relative abundance is prevalence or frequency. Examples include the proportion of traps catching animals per night, or the proportion of plots where an animal or its sign is observed. This method is attractive because the data is easily collected and calculations for comparision can be made by testing the significance of proportions; e.g. the proportion of traps capturing mice in 'habitat a' versus 'habitat b'. This method, however, also has disadvantages. For example, collecting presence/absence data on plots assumes all animals have an equal probability of occurring on the plot at the time of sampling. In fact, most wildlife species have clumped distributions. For trapping, it is assumed that all individuals are equally catchable. For many wildlife species catchability varies between individuals. Frequency measurements of this kind usually require a density-frequency transformation (Caughley 1977).

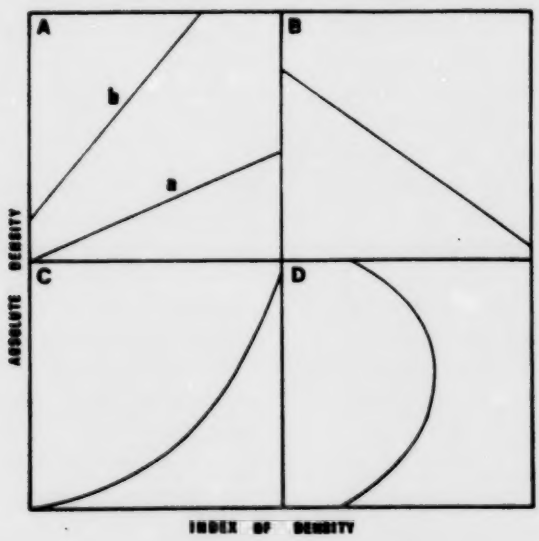

Figure 3. Various forms taken by the regression of absolute density on an index of density: (A) linear ascending, (B) linear decending, (C) non-linear, and (D) non-linear recurvate (from Caughley 1977).

DEMOGRAPHIC VIGOR

Demographic vigor is the survival-fecundity rate of change (r_s), or the rate implied by prevailing schedules of age-specific survival and fecundity (Caughley 1977). The demographic vigor of a population is its level of well-being, and describes the average reaction of all members of a population to the collective action of all environmental variables (Hanks 1981). Demographic vigor is therefore of considerable interest in assessing population dynamics. Unfortunately, there are many difficulties and tautologies associated with the measurement of r_s (Caughley 1977). One alternative is to calculate the finite potential rate of change from annual estimates of recruitment and adult mortality, i.e.

$$\lambda p = \frac{1 - Mn}{1 - R}$$

where λp is the finite rate of change in the absence of harvesting, R is the recruitment rate (proportion of new recruits in the adult population), and Mn is the adult natural mortality rate (Hatter and Bergerud 1991). R can be measured from recruitment surveys, while Mn is commonly measured from radio-telemetry studies of adult mortality.

Eberhardt (1977) has suggested that long-lived species follow a predictable sequence of demographic events as they approach the carrying capacity of their habitat. The sequence is::

1. juvenile mortality rate increases;
2. age at first reproduction increases;
3. adult reproductive rates declines;
4. adult mortality rate increases.

This model offers some useful insights for population monitoring and suggests that different parameters should be measured, depending on the population's position on its growth curve. Specifically, we may expect juvenile mortality to be the vital key parameter in the analysis of demographic vigor (Hanks 1981). Radio-telemetry and mark-recapture experiments can be used to measure this parameter.

INTERPRETING TREND-LINES

Finally, a cautionary note about interpreting trend-lines. By definition, a population trend is detected when a linear regression of abundance (usually $\log_e$ [numbers or index of numbers]) versus time has a slope (observed rate of change) significantly different from zero (Harris 1986, Gerrodette 1987, Fig. 4). The conclusion that a trend in abundance is occurring, when in fact it is not, is termed a *Type 1* error, while the conclusion that no trend is occurring, when in fact it is, is a *Type 2* error. All too often, we ignore the *Type 2* error and infer no change in abundance when the regression is not significant. I strongly suggest that biologists make use of power analysis to determine the 'sensitivity' of their data for detecting trends (Eberhardt 1978). Power analysis for trend-line monitoring is discussed in detail by Gerrodette (1987).

CONCLUSIONS

In conclusion, I believe the choice of which population characteristics to measure, be it absolute abundance, relative abundance, or demographic vigor, will only depend partially on biological considerations. For efficiency, the selection of what to measure will be dictated by constraints related to specific objectives, sampling efficiency, statistical concerns, and budgets. For many species, the appropriate inventory methods to measure a broad array of population characteristics are reasonably well known (Davis 1982). For these species data collection, analysis, and interpretation should be relatively straightforward. For other species, however, more research and development of suitable cost-effective inventory techniques and methods of analysis will be required.

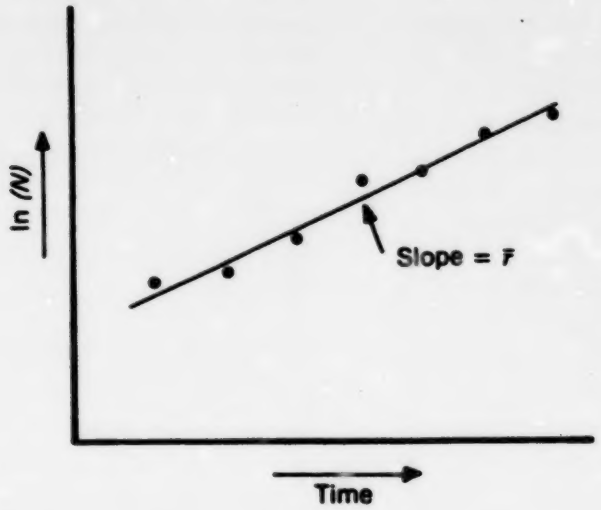

Figure 4. The estimate of *r* when natural logarithms of animal numbers are plotted against time (from Hanks 1981).

RECOMMENDATIONS

1. Conduct a cost-benefit analysis for developing an expert system on inventory techniques. Ideally, a PC-based expert system should be considered. This would allow a user to quickly and efficiently select the most appropriate population inventory method for a particular species in a given habitat, under specified objectives and constraints. Both absolute and relative abundance methods should be considered.

2. Develop minimum standards for the use of a population census method. The following minimum census standards are proposed: (1) that the accuracy of the method be verified with a known population, or (2) that two completely independent census methods give similar results. Further, the estimated variance of the observed mean should be given or 95% confidence limits provided.

3. Develop minimum standards for the accuracy and precision of measured population characteristics. Impact studies will require specifying probabilities for making *Type 1* and *Type 2* errors, as well as a minimum change in population size that would result in a change in management action. Baseline studies can probably be handled by specifying confidence intervals. For some studies, 95% confidence intervals that are less than ± 25% of the mean might be required, whereas for other purposes ± 50% could be adequate. Monitoring studies will probably require both approaches.

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A RECONNAISSANCE METHOD FOR MONITORING WILDLIFE IN THE FIELD

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(introduction by author with notes by editor)

The following introduction from the manual for monitoring wildlife in managed forests (Hatler 1992) provides a background and some general uses of the monitoring method.

Successful practice of integrated forest management requires detailed knowledge of the characteristics and interactions of the resources involved, and an understanding of how various management practices affect them. In response to the need for obtaining better information on the relationship between wildlife and silviculture in northern British Columbia, FRDA project 1.49 was set up to develop a simple and practical wildlife monitoring method. This document is for use in the field as a procedures manual and reference for that method. A short training video is also available, and is recommended for first-time users.

The terms "wildlife monitoring" and "environmental monitoring" have distinct meanings in this document. The former refers to the procedures described herein; the latter, focusing on physical and vegetative habitat features, refers to the monitoring system developed jointly by the B.C. Ministries of Environment and Forests (Habitat Monitoring Committee 1990). The wildlife monitoring method and associated data forms have been designed to be compatible with those for environmental monitoring.

A detailed account of the rationale and development of the wildlife monitoring method, together with examples of its use and a literature review, are provided in a separate report. Some essential points about the method's application and limitations are noted here:

- It provides reconnaissance level information on wildlife occurrence. It is not intended to replace formal research on forest ecology matters, although results are expected to be useful in indicating information gaps and identifying future research projects;

- It is useful for comparing two or more areas, such as treatment and control sites or different habitat types, or for monitoring changes in one area over time;

- It is not appropriate for very small research or treatment plots. Firm guidelines on the minimum size of potential project areas are not yet possible, but will probably relate to home range sizes of common wildlife species;

- Results from the method will be most meaningful if they can be correlated with vegetation or other habitat data. Companion environmental monitoring studies are therefore recommended.

(end of introduction)

The following analogy was offered by D. Hatler to all who were going too fast from the business of managing species to that of managing for biodiversity, "Learn to crawl before you run a marathon".

In the evening, Art Lance presented his experiences when using the "Hatler Method". He compared the one and the two person methods, talked about some adaptations he made to the method and the utility of the method.

Some of A. Lance's comments about his trials of the method:

- the one person application resulted in 75% of the data found via the two person method, and it took 1 times as long to complete;

- with 2 people, there can be greater concentration by the observer with jobs like navigation and recording being taken care of by one of the team;

- people have to be efficient at handling data as there can be up to 80 codings for a single species;

- there needs to be an effort made to demonstrate that there is independence between observations with the linear transects;

- random vs. homogeneous; routes were chosen to encompass as much of the block as possible without crossing roads or each other and so that they did not go along edges, therefore the sampling in this test can not be considered random;

- biological reasons for non-independance are more important than statistical reasons;

- relative observability; the ease with which you can see the animal. To allow for this, run an independant trial doing a standard test for visability - the result being a VISINDEX;

- confounding variables include summer vs winter and observer vs observer;

- it is very difficult to find controls for such experiments. This is a difficult problem to overcome and seeking cooperation from operators and Ministry of Forests was recommended.

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ARTHROPODS - WHERE DIVERSITY IS REALLY AT

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INTRODUCTION

In British Columbia, a good guess at the number of terrestrial arthropod species would be about 40,000 to 50,000. In other words, there are about ten times as many arthropod species as there are plants and about 100 times as many as birds. No thorough studies have been done for smaller areas in British Columbia, but in the H.A. Andrews Experimental Forest in Oregon (6400 ha), 3400 species are known, although this is estimated to be only half the actual total number living here (Lattin 1990). At a still smaller scale, it is estimated that in the litter zone of mature forest in Oregon, species richness reaches 250 species per square metre. Every time you take a step in such a forest, your foot is being supported by 16,000 invertebrates held up by an average of 120,000 legs (Moldenke 1990)! In the canopy of coastal forest, 500 species have been found in the tops of three Douglas-fir trees in Oregon (Lattin 1990) and at least as many have been found in two or three Sitka spruces on Vancouver Island (Winchester, pers. comm.). It is abundantly clear that arthropods play a major role in the ecology of our forests. It is equally clear that, if we can surmount the logistical problems, the study of insects and other arthropods has the power to give us a high resolution picture of the biological diversity of an area and its microhabitats. In fact, depending on the scale of the study and the habitats in question, arthropods may be the best group of organisms to focus on.

TECHNIQUES

The various techniques used to collect and sample arthropods are almost as diverse as the organisms. They are reviewed in detail by Martin (1977). Here are ten of the most common methods that sample a wide variety of species.

1. Pitfall or pan traps - These are simply vessels placed on or in the ground that capture arthropods that stumble into them and cannot climb out. Usually a liquid preservative such as ethylene glycol (poisonous to vertebrates) or saturated salt water is placed in the bottom to preserve the catch and trap flying insects that land in the container. Groups such as ground-inhabiting spiders, ground beetles, ants, grasshoppers, and many flies and wasps are well sampled using these traps. The traps are inexpensive, easy to set up, and require little monitoring effort. Various enhancing devices can be added, such as fences to divert walking arthropods to the trap, covers to protect the catch from rain, and a variety of baits (Figure 1).

2. Flight intercept traps - The most common type of flight intercept trap is the Malaise trap, a tent-like affair which works on the principle that many flying insects try to get around an unexpected barrier by flying upwards. This captures many flies and wasps that otherwise would go

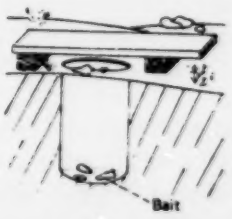

Figure 1. Pitfall trap with cover. (From Borrer *et al.* 1976.)

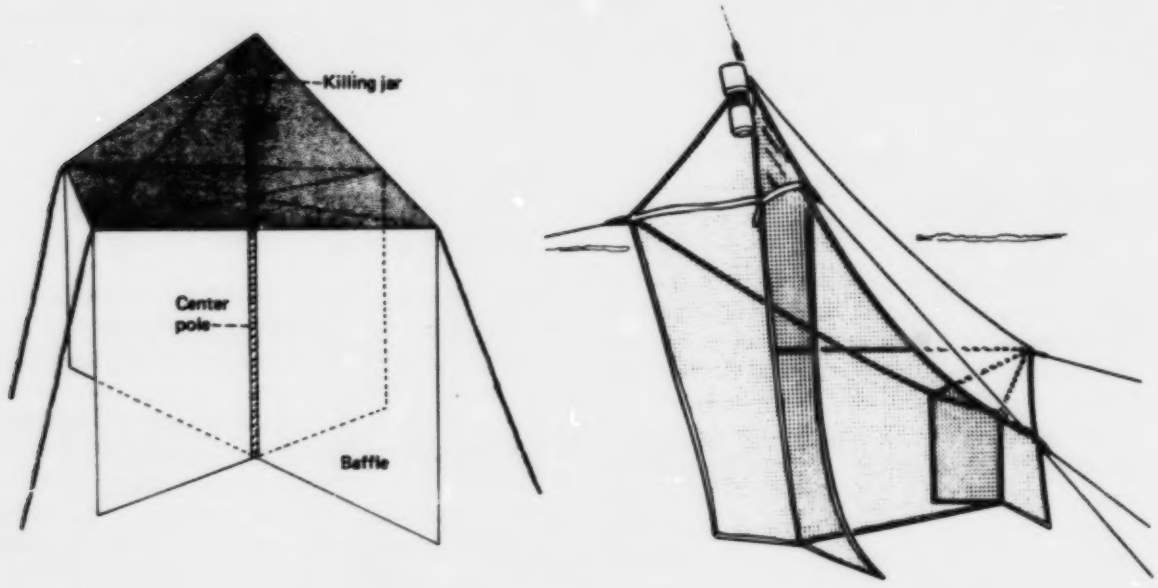

Figure 2. Two styles of Malaise traps. The one on the left is from Martin 1977, the right from Borror *et al.* 1976.

undetected. Window traps capture beetles and other insects that drop when they hit a barrier. These two traps can be combined by placing a liquid-filled pitfall trap along the base of the central wall. The success of flight intercept traps is very dependent on their placement and weather conditions (Figure 2).

3. Suction traps - These eliminate the biases of traps that require the active participation of flying insects to find their way to the collecting vessel; they are designed to simply suck the insects out of the air in a certain area (Figure 3).

4. Light traps - There are a variety of designs of traps involving lights; some researchers prefer specimens manually taken from white sheets hanging behind the lights. Mercury vapour lights work the best, combining ultraviolet and visible wavelengths in a very bright light. These lights can be very good at sampling certain nocturnal, flying groups; others are not attracted. Capture success is also dependent on evening temperature.

5. Tullgren or Berlese funnels - These devices are used simply to extract the arthropods collected in soil and/or litter samples. The sample is placed over a screen in the funnel and a heat source (usually a light bulb) is placed above the sample. The insects, mites, etc., move away from the heat and drying effect of the lamp and fall through the screen into a collecting vessel (Figure 4).

6. Sieves - These simply do manually what the Tullgren funnel does automatically. They are probably more appropriate for slightly larger invertebrates than many of the mites and collembola extracted by the funnels, and can be used easily in the field as the sample is collected.

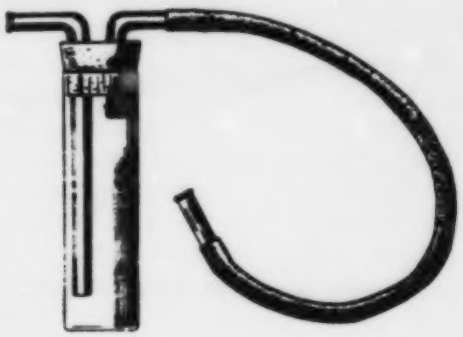

Figure 3. A mouth operated, vial aspirator. (From Borrer *et al.* 1976.)

7. Emergence traps - Emergence traps are usually clear or translucent, cone-shaped devices that trap insects emerging from their larval or pupal habitat in the water or ground, and guide them to a collecting vessel.

8. Sticky traps - These are very effective at sampling small, flying insects but produce poorly preserved specimens that are difficult to identify to the species or even genus level. Experts will often refuse to deal with such messy specimens.

9. Rearing - Rearing is a labour-intensive but valuable method for determining the identity of larval specimens or galls collected in the field. It also produces valuable data on the prevalence and identity of larval parasites.

10. Manual collecting - Manual collecting is still the best method for capturing many flying insects, insects that are closely associated with vegetation, and insects that are closely associated with a particular microhabitat. A variety of nets are used,

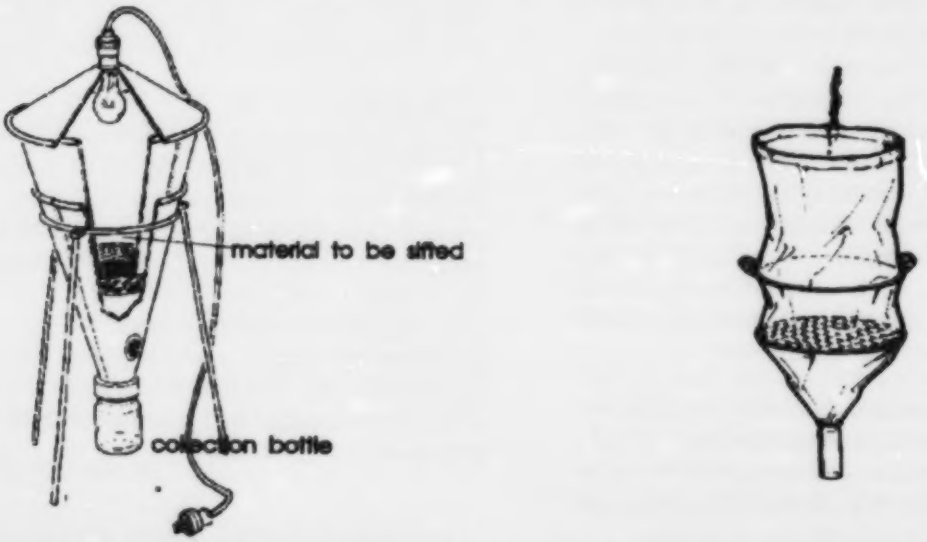

Figure 4. Two Berlese funnels, the second a collapsible canvas model. (From Martin 1977.)

Figure 5. An insect net turned to prevent the escape of captured specimens. (From Borror *et al.* 1976.)

from typical 'butterfly' nets (Figure 5), to heavy-duty sweep or beating nets used for collecting insects from herbs or shrubs, to nets specialized for collecting aquatic invertebrates. Various types of aspirators, or 'pooters' are also used to collect small insects with a minimum of handling. These techniques do not lend themselves easily to quantitative sampling; methods such as 'standard sweeps' are sometimes employed.

CAUTIONARY NOTES

One of the main problems inherent in invertebrate surveys is simply the overwhelming species richness. Not only are there a lot of species in British Columbia, but little research has been done so most groups are poorly known. It is not uncommon to collect a number of species previously unknown to science in a brief survey of an area in southern British Columbia (Cannings 1990, Cannings and Cannings 1992). Even in groups such as butterflies and dragonflies, for which we may have reasonably accurate species lists for the province, the distribution of many species is only shakily known. Poor baseline information makes it difficult to draw meaningful conclusions from the data collected at a specific site.

In addition to the problems with sampling and replication inherent in other surveys, there are a number of technical and logistical problems unique to arthropod collecting. Three of these that come to mind are:

1. Variation due to weather
Because they are small, poikilothermic animals, the activity of arthropods (and especially the flight of insects) is directly tuned to air temperature, sunshine, wind, and precipitation. Variations in these weather attributes will greatly affect the numbers and species of arthropods sampled, especially with Malaise traps and light traps. To reduce these effects, comparative sampling must be done at the same time and in close proximity;

2. Seasonal variation
Arthropod life cycles can be brief, and the stage to be sampled may only be present for a short time each year. Therefore, for an accurate picture of the arthropod community, sampling must be done periodically throughout the entire active season;

3. Specimen overload
Effective trapping methods are needed to sample a wide variety of species, but these methods (combined with the need to sample throughout the active season) also produce immense numbers of specimens. One can quickly gather enough material to keep several people busy the rest of the year. The processing of these specimens (sorting, mounting, labelling) is a skill requiring training and practice, and will probably account for the majority of the budget for a thorough study of the arthropods in a given area.

4. Specimen identification

Identification of samples is an even bigger hurdle than processing, since it requires both extensive training and access to a good reference collection. Identification keys to most of the arthropods of British Columbia simply do not exist, and those that do exist are often difficult and time-consuming to use without a collection at hand. By far the most efficient way of identifying specimens is to have an expert do the job, but experts are in short supply (indeed, for many groups there are no experts). (It is ironic that, at a time when the demand for their services are rising rapidly, the number of experts working at the Canadian National Collection of Insects at Agriculture Canada has declined significantly in the last few years.) Finally, if we are to use the samples taken in a survey effectively, the specimens must be deposited in a curated collection; museums here and elsewhere are notoriously poorly funded, so additional funding and personnel must be set up in advance to handle acquisitions.

PRIORITIES

What can we concentrate on to avoid completely overloading ourselves and wasting our resources? First, we really need some good, thorough baseline studies in key regions and habitats. Second, we must identify certain habitats or microhabitats that are appropriate to the questions we are asking and then identify particular arthropod groups that would be useful in characterizing the diversity associated with those habitats. These groups should be diverse within the habitat, be relatively well-known (i.e. few undescribed species present) and have an expert who is available and willing to identify them to the species level. In coastal forests, for example, we might key in on rotting logs on the forest floor, moss/lichen epiphytes in the canopy, and stream habitats. Appropriate arthropod groups to key in on within those habitats would include collembola, spiders, beetles, and aquatic insects.

CONCLUSIONS

The study of arthropod distribution can provide us with detailed knowledge of the structure and function of forest ecosystems. However, it is a field one cannot jump into and study with a tiny budget and with limited expertise on staff. If we are serious about studying this major part of our biological heritage (and we should be), we must begin by addressing the shortage of expert taxonomists and trained technicians by supporting university programs and research in the field of arthropod systematics and distribution in British Columbia. Collections such as the Royal British Columbia Museum, the Canadian National Collection (Agriculture Canada) and the Spencer Entomological Museum (University of British Columbia) need to have adequate funding in order to provide a sound basis for our knowledge of arthropod distribution and ecology. Without these repositories and centres of research and expertise, field collecting is a pointless exercise.

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MONITORING LARGE MAMMALS IN WILDLIFE DIVERSITY STUDIES

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HABITAT STUDIES OF LARGE MAMMALS

Habitat preferences of large mammals are typically determined either by:

1. Following individual animals to determine the use of different habitat types within their home range and comparing what they use with what habitats are available; or

2. Comparing indices of large mammal activity in different habitat types.

Monitoring of radio-collared animals is the primary method used to determine habitat use of individual animals. There have been numerous radio-telemetry studies on a variety of large mammal species in British Columbia including grizzlies, caribou, deer and moose. The only other methods that may allow extended monitoring of individual animals is following tracks in the snow or following animals that have been habituated to human presence. Tailing in the snow has been used to provide habitat information on deer (H. Armleder, S. McNay) and caribou (K. Simpson, D. Cichowski, B. McLellan). Habituated moose in Alaska and black bears in Minnesota have been followed to provide habitat use information.

There are various indices of animal use that can be used to compare relative abundance in different habitat types. Simple counts of animals (from the air or ground) in different habitats can be used but obviously these can be biased by differences in the visibility of animals in different habitats. Track counts can provide a valuable index of animal use, especially in winters with good snow conditions for tracking (M. Waterhouse and H. Armleder). However, ideal conditions for track transects are not common.

Feeding activity (browsing or grazing intensity) can indicate the relative amount of use of different habitats by ungulates for feeding. Scat or pellet counts can also provide an index of relative abundance in different habitats. Ideally, scats should be first cleared from marked plots or transects and then those plots should be regularly checked to count and remove new scats. Regular monitoring of previously cleared plots eliminates biases due to differential decay rates in different habitat types and will also provide information on seasonal changes in degree of use. scat counts will not accurately reflect habitat use if the defecation rate differs in different habitat types. Most ungulates defecate more in bedding areas than in feeding areas.

Motion-sensitive cameras provide a possible method to monitor large mammal use in different habitat types (F. Hovey and B. McLellan). The number of photos of different species can be used as an index of relative abundance. Recent technological improvements have greatly increased the feasibility of using motion-sensitive cameras.

MONITORING LARGE MAMMALS IN BIODIVERSITY STUDIES

Many components of biodiversity including plants, insects, small mammals and most birds can be studied in relatively small study plots (1-25 hectares). In contrast, most large mammals have home ranges ranging from 50 to 25,000 hectares. Consequently, there are major problems in at-

tempting to study large mammal use of small study plots that are adequate for studies of smaller species, or on small areas where alternative forestry practices are being evaluated.

If biodiversity study plots or modified treatment areas comprise only a minor part of the home range of a radio-collared large mammal, use of those areas by the radio-collared animal will generally be very low unless the area contains some unique feature such as a mineral lick or den site. Therefore, it will be almost impossible to statistically demonstrate if the animal selects or avoids any particular small area within its home range. In order to detect the response of radio-collared animals to a new forest or land management practice, the treatment areas should cover a substantial proportion (>10%) of the animals' home range.

It is possible to measure indices of large mammal use on small study areas. However, because large mammals are generally at lower densities than smaller species, detection rates in a small study area will usually be quite low and require extensive sampling to obtain a sufficient sample size of detections. Of greater concern is that if the sampling area is a minor component of the animals home range, use of the area will be greatly influenced by adjacent habitat types. It will be difficult to determine to what degree the use of any particular stand is being influenced either positively or negatively by the characteristics of adjacent habitat types. The best solution to the problem of adjacent habitat influences is to sample many replicates of the habitat or treatment type in different areas.

CONCLUSIONS

Our knowledge of large mammal habitat use is fairly good for many species in British Columbia as a result of numerous radio-telemetry studies. Information on large mammal habitat use is generally much better than for other animals. It is not necessary for large mammals to be included in every biodiversity study, especially if data on habitat use is already available.

In general, landscape level radio-telemetry studies with associated site inspections are usually the best approach for studying large mammal habitat use. Evaluation of modified forestry or land management practices by monitoring radio-collared animals should not be attempted unless the treatments comprise a significant component of the animals home range.

Indices of large mammal use can be measured in small areas but a major sampling effort is required to get an adequate sample size. Monitoring of large mammal use of biodiversity study areas cannot be a trivial add-on to studies of other species. Due to potential influences of adjacent habitat types on use of any one stand, sampling must be replicated in numerous stands or treatment areas. The small number and size of alternative silvicultural treatment areas that are presently available precludes us from effectively evaluating the impact of those treatments on large mammal species.

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MONITORING METHODOLOGY FOR SMALL MAMMALS

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(based on overheads and literature provided by the speaker and notes from the editor)

SAMPLING TECHNIQUES

For evaluating **species and abundance**:

1. Live-traps, used in mark/recapture studies provide dynamic sampling. A variety of live traps are available, including, Longworth, Sherman Tomahawk and Have-a-Heart. When the animal is caught, eartags can be affixed and weights and other measurements taken.
2. Pitfall traps can be used for both dynamic and static sampling.
3. Kill traps are static samplers.

COMPARISON OF TRAPPING METHODS

DYNAMIC SAMPLING	STATIC SAMPLING
Multiple census	Single census
Time series	"Snapshot" in time
Seasonal variation	No variation
Common and rare species	Common species
Population dynamics	Trap-nights

The following are methods of censusing **habitat use:**

1. Radio-telemetry
2. Track counts
3. Fecal pellet counts
4. Sightings

The larger small animals (e.g. hares) move over a large range, therefore it is difficult to determine habitat use by trapping, and some form of tracking is required.

LIMITATIONS AND INTERPRETATION

For all methods there will be seasonal and yearly variation, making conclusions difficult to draw, particularly if a single sample has been taken. (e.g. Figures 1 and 2).

Disruption of populations and communities must be considered when sampling. Once the existing species have been removed there may be rapid recolonization of the area by less common species. A very different community will be the result. The question arises, "Would they be the first colonizers after a disturbance like herbicide treatment, clearcutting or partial cut?" The population in the long term may not be stable, yet first samples may show the species in abundance (Table 1).

Lastly, when interpreting the data, the possibility of biased or misleading results must always be considered.

TABLE 1. Removal response of less common species.

	Control		Treatment	
	Non-Removal	Pulse-Removal	Non-Removal	Pulse-Removal
Long-tailed Vole *Microtus longicaudus*	6	11	4	39
Red-Backed Vole *Clethrionomys gapperi*	3	21	2	0
Jumping Mouse *Zapus trinotatus*	5	14	5	3
Shrew-mole *Neurotrichus gibbsii*	1	9	10	20

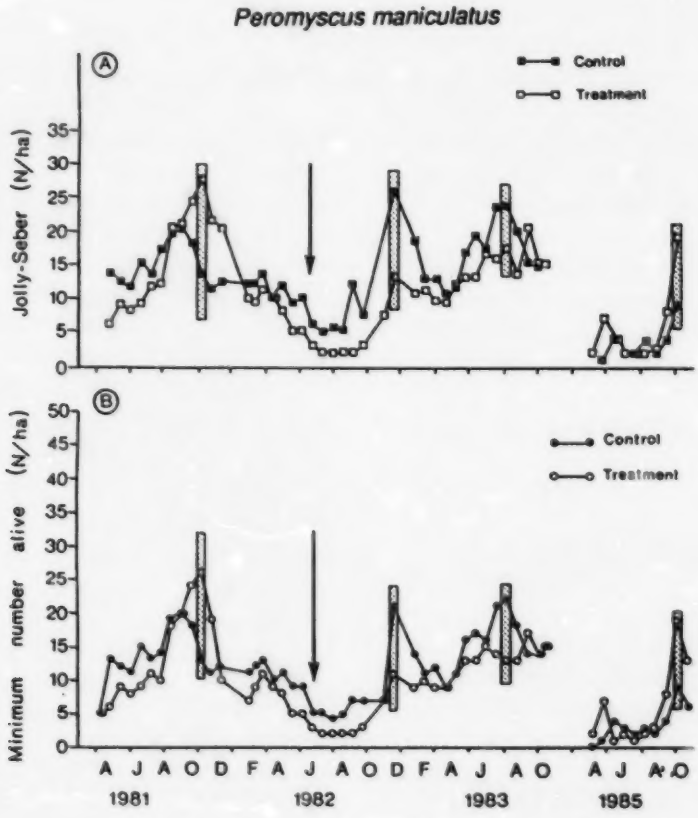

Figure 1. Population density (A: Jolly-Seber, B: MNA) of deer mice on control and treatment grids during 1981 to 1985. Vertical arrow indicates when glyphosate herbicide was applied to the treatment area. Shaded bars represent specific sampling periods which have significant differences in density of mice between areas. (From Ritchie and Sullivan 1989).

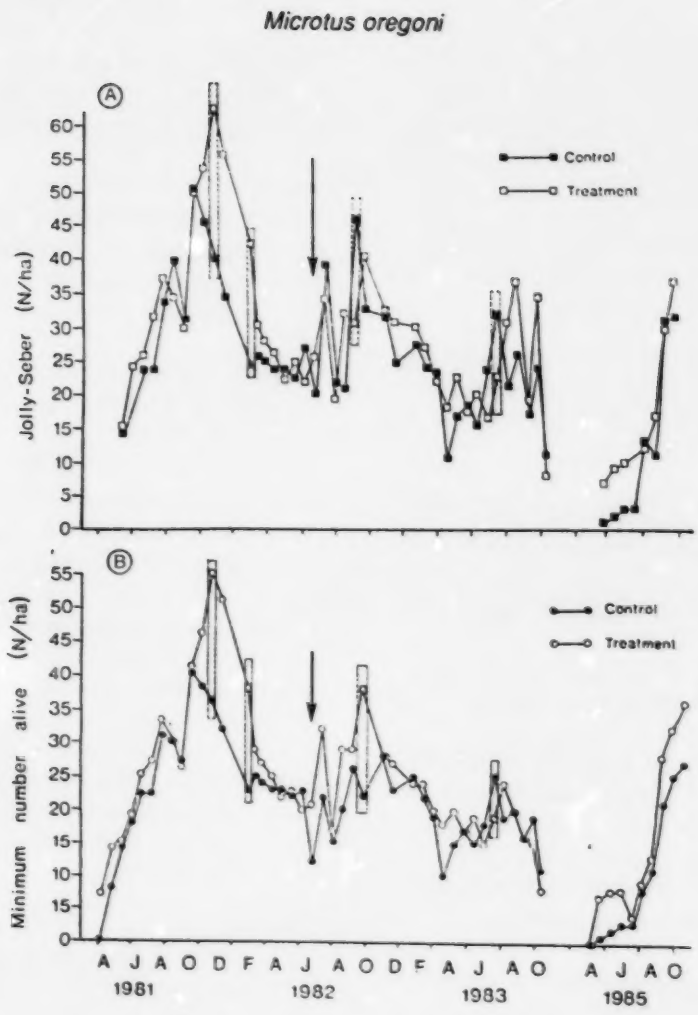

Figure 2. Population density (A: Jolly-Seber, B: MNA) of Oregon voles on control and treatment grids during 1981 to 1985. Vertical arrow indicates when glyphosate herbicide was applied to the treatment area. Shaded bars represent specific sampling periods which have significant differences in density of voles between areas. (From Ritchie and Sullivan 1989).

RECOMMENDED SAMPLING SCHEME

1. Set in place grids of live-traps for the duration of the study;
2. Have 2,3 and 4 week intervals when trapping;
3. Do mark and recapture studies;
4. Make a detailed analysis of all species over time;
5. Use a package computor programs for the PC. One such package is:
   Small Mammal Programs for Mark-Recapture Data Analysis, by Charles J. Krebs, Department of Zoology, University of British Columbia, Vancouver, B.C., V6T 2A9.

ETHICS

Dr. Sullivan raised several questions under the topic of ethics. They are all thought-provoking and should be considered during the planning process:

1. Should old-growth forests be the "standard" by which everything else is measured?

2. Should we be disrupting essentially undisturbed ecosystems?

3. Are all species equal?

4. When there are limitations in time, funds, motivation and talent, should the team approach be taken?

5. Should fewer studies be done well rather than many studies done poorly?

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MONITORING BATS AND FURBEARERS FOR BIODIVERSITY STUDIES

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INTRODUCTION

Bats are an important group of mammals that should be included in biodiversity studies. Of the 114 species of terrestrial mammals indigenous to British Columbia, 16 are bats (not including the single record of the big free-tailed bat found in New Westminster in 1938). Bats comprise 14% of the terrestrial mammal species and several are red- or blue-listed. Most species of bats are associated with forests and all have special habitat needs for reproduction and roosting (for example, tree cavities, exfoliating bark, or caves). Most bat species form maternity colonies and thus are vulnerable to single disturbances.

Furbearers are also an important group of mammals that should be included in biodiversity studies. Most furbearers are secondary consumers and thus dependent on small- and medium-sized mammals and birds. Most furbearers are forest-dwelling or forest-associated species. They have large home ranges and are more sensitive to landscape level changes to their environment than are small mammalian herbivores that can live within a small patch of habitat, or birds that can move among small patches of habitat.

METHODS

1. Bats

Techniques used for monitoring bats are similar for nearly all species of bats. Because bats can be infected with rabies, use caution and protective gloves when handling bats. In eastern Canada, approximately 1/1000 wild-caught bats test positive to the rabies antibody test. This doesn't necessarily mean they have rabies, but indicates they have been exposed to the rabies virus. Do not handle bats that behave unusually or are crawling on the ground.

Relative numbers and species of bats using an area can be determined by stringing mist nets across a flyway such as a creek or roadway. Data obtained by mist netting is usually biased because different species of bats fly at different heights (Figure 1).

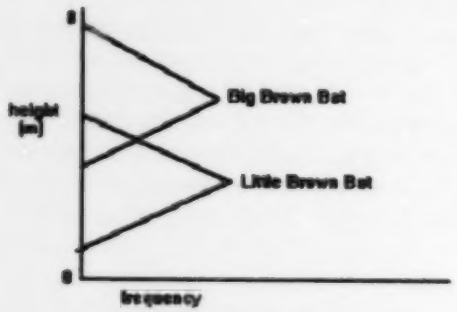

Figure 1. Catches of bat species, dependant on net height.

A second method of capturing bats is with a harp trap or Tuttle trap. This trap is constructed by stringing monofilament lines vertically across a frame. Beneath the frames a trough-shaped plastic lined bag is positioned to catch bats that hit the lines. Like data from mist nets, data from Tuttle traps are biased because the species caught depends upon the height at which the trap is located (Figure 2).

Commuting and foraging bats emit a stream of echolocation calls that aid them in navigation and capturing prey. These ultrasonic calls are in the 20 kHz to 100 kHz range and can cover a range of frequencies. Many species of bats have distinctive calls, but some species cannot be readily distinguished by their call alone. A variety of ultrasonic detectors are available which can be

Figure 2. Harp trap in front of cave.

used to monitor bats. The most basic detector is a leak detector for natural gas lines and is sensitive to 45 kHz. Another detector, designed for monitoring bats, is the QMC bat detector ($300). It can be tuned to a series of frequencies but only one frequency at a time. These simple detectors tell you there are bats nearby and you can count the number of passes, thus obtaining an estimate of bat activity. You can not normally determine which species of bats are present without verification by captured specimens. The QMC detector has a detection radius of up to 5.8 to 8.5 m. More sophisticated ultrasonic detectors are available and can cost up to $20,000. With these detectors, you can identify many of the species by their sonogram. However, even when the sonogram can be viewed, some species of bats are difficult to tell apart.

Regardless of the equipment used to monitor bats, three aspects of bat biology make population estimates difficult to obtain:

1. bats have several peaks of activity during the night and thus the monitoring schedule must be designed to account for this activity pattern;

2. bats are colonial and don't disperse at random from the colony at night. This contributes to a high variance at monitoring sites and thus a large sample size is needed;

3. some species of bats are rare or uncommon and you will obtain a low detection rate even with sophisticated equipment and experienced personnel. The low detection rate gives high variance in data and large sample sizes are required.

2. Furbearers

The main monitoring methods for the furbearers are track transects, live trapping and remote cameras. Track transects in snow can provide relative estimates of densities if you assume number of tracks/km are positively correlated with population density. Several factors exist which could bias estimates:

- number of days since the last snowfall;
- hardness or crusting of snow; and
- differences in snow hardness among habitat types.

Even if these factors are accounted for, estimates derived during the winter can not be extrapolated to other seasons. During summer or snow-free periods, tracking boards (either sooted aluminum plates or florescent powder) can be used to estimate relative numbers of individual species.

Most of the furbearers can be live-trapped using wire cage live-traps (eg. Tomahawk and Havahart traps) baited with fish, meat, or jam. Bedding must be provided in the traps to prevent hypothermia and the traps must be checked daily. After capture, the animal can be placed in a holding cone to allow safe handling and ear tagging. The number of animals caught per trapnight can be used as an estimate of relative density. If the animals are eartagged and then later recaptured population densities can be calculated. Trapping success of mustelids is low compared to that of small mammals and thus substantial effort is required to obtain even relative population estimates.

Remote cameras offer an alternative method to live-trapping. They have been used successfully in some studies but are a relatively new technique and pose problems to the interpretation of data.

SUMMARY

The methods used to monitor bats and furbearers depend to a large part on what question is being asked. The species we are most concerned about tend to be uncommon or rare. This makes monitoring difficult from a statistical aspect. For some species of bats, perhaps presence or absence is all that is required and likely all that can be provided even with the most sophisticated equipment. Before beginning the study, decide whether estimates of density are needed or whether relative density provides sufficient information to meet the studies' objectives. After this decision is made then appropriate methodology can be chosen and a sampling scheme designed.

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METHODOLOGY FOR MONITORING FOREST BIRDS IN THE CONTEXT OF WILDLIFE DIVERSITY IN B.C. FORESTS

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INTRODUCTION

Thank you for inviting me to speak today. I would like to bring an East Coast perspective to the workshop by sharing my experience from 13 years of songbird research related to forest pesticide applications. I have been involved in probably the largest scale experiment in North America, 30 years of spruce budworm surveys covering 1-3 million ha of Eastern Canada in any 1 year. This was not a biodiversity study, but some of the lessons apply.

Immediate effects were only apparent with insecticides highly toxic to birds directly. Most effects were delayed, partly due to site tenacity of the birds, but also due to complexity of the ecosystem processes involved. I am referring to biomagnification of toxins and indirect effects on survival of young through a depletion food resources. Subtle effects on reproductive success were generally not translated to population level responses.

This large scale experiment has revealed the importance of birds as predators of forest insects and as indicators of ecosystem health. Despite this onslaught of chemicals, we have not measured a decrease in diversity relative to spraying. This raises an important question: are there broader scale decreases in neotropical migrants masking the effect of management practises we are trying to measure?

WHY INCLUDE BIRDS IN A BIODIVERSITY STUDY?

Birds are easy to monitor and potentially sensitive to forest management practices. They are integrators of a variety of lower level processes (involving invert prey, fruit and seed production) and they influence forest development over time by recycling nutrients. They are mobile habitat selectors, able to select habitat over a landscape level that other taxa cannot. They are the public's gauge of ecosystem health.

As it is impossible to measure all habitat variables, birds can provide a measure of ecosystem components. For example, a wildlife tree is really defined by whether it is used or not.

HABITAT RELATIONSHIPS BETWEEN BIRDS AND FOREST

Numerous studies have related number and diversity of birds to availability of critical resources; vegetation volume has been correlated with breeding bird density (presumably by providing prey, nest sites or cover; Erdelen 1984; Mills *et al.* 1991).

Yet merely increasing habitat diversity may in fact threaten some species, for example, habitat specialists such as the northern spotted owl, that require uniform conditions . Nor is it sufficient to maintain or protect habitat, as it may become

unsuitable for habitat specialists such as the Kirkland's warbler that requires pine trees 1-6 m in height. There is a need for understanding.

The main approach in detailing habitat needs has been to characterise territories of bird species censused in the study area and to compare habitat components of their territories to that of the area in general. Examples:

1. minimum habitat needs (Haila *et al.* 1989);

2. the multidimensional habitat-niche approach (Noon 1981). Vegetation samples are taken in randomly selected locations within the study plot, bird territory maps are overlaid and the data is summed from sample sites that fall totally within territories for each bird species separately. The structural components of habitat are compared between species and against a random sample of available habitat for each species. [See Bekoff *et al.* (1989) or Sakai and Noon (1991) for characterising nest location as factor in nest success].

To determine the biological significance or reality of bird-habitat correlation patterns, it is necessary to either:

1. directly observe bird behaviour (territories may include a number of habitat types); or

2. manipulate the habitat and monitor the response of individuals or populations (eg. habitat removal with a herbicide).

SUMMARY OF TECHNIQUES

- censuses using point counts and spot-mapping can be used for all groups presented (see Ralph and Scott 1981);
- because of the territories of woodpeckers and owls, other techniques should be used to supplement these censuses;
- for owls, walk a transect stopping at predetermined distances (500 m) and play a recorded call of the species, listen 1 minute, continue; roost trees are located by traversing the area and looking for "whitewash" or pellets - playback also used for songbirds to map territory boundaries more finely;
- radiotelemetry used to determine movement of individuals, territory size and habitat use, particularly for woodpeckers and owls but also songbirds;
- capture/recapture is used to determine emigration, immigration, survival, and parentage.

An important contention between ornithologists is whether to use a spot-mapping or point-count method. The use depends on your objectives and the amount of money available. Every ornithologist has their bias and I will give you mine now.

1. Spot-mapping

Spot-mapping, because the observer traverses the area, is less efficient and less area can be covered. However, this method allows the observer closer contact with the birds enabling simultaneous observations of behaviour. They are more likely to find nests, see fledged young, and make observations of habitat use. It provides a density measure, and density is a better index of habitat response than simple species presence or absence (Weins 1985).

Design:
- minimum 5 visits, minimum 10 ha taking about 2 hour, walk every 2nd line, rotate observer and route.

Concerns:
- movement of individuals, interpreting territory clusters limited to breeding season (stationary), can't detect abundance of floaters.

Type of data:
- territories, distribution patterns density estimate, annual indices of population levels, species composition of a community and relative abundance of different species, measure of subtle changes of abundance, territory location and size.

Examples:

- Thompson *et al.* 1992, Freedman *et al.* 1981, Millikin, (in prep).

2. Point count

As a large number of sample stations can be covered, this method is used for large scale population trends relating localised distributions to forest habitat types or identifying critical geographic regions; the risk is accuracy.

Design:

- observer remains stationary using a fixed (75 m) or open radius census area, 4 visits, observation time 3-12 minutes [10 minutes is optimum in my experience, but this depends on forest closure, density and diversity of the bird population (>10 increases chance error due to movement of counted birds, with <10, less abundant and less vocal birds tend be underestimated; a 10 minute count is also less subject to effects of time of day)].

Concerns:

- less accurate placement of birds, so observer may include birds from a larger area if fewer are singing (use a fixed distance so loud singers won't be counted on a larger area), more sensitive to problems with masking of individuals, disturbance and ability of observer, unsure about individual birds, their behaviour or movement.
- I recommend that a long term sampling plot be used to test the count method so that the sampling regime required to detect inconspicuous species can be determined.

Type of data:

- number of sample plots occupied by species X giving an estimate of species associated with a particular point; several points are needed to cover variability.

Examples:

- Welsh (unpublished) inventory and habitat association baseline data to monitor population trends in Ontario; Eckert *et al.* (in prep).

3. Fixed width transect with spot mapping

I found a good compromise is the fixed width transect with spot mapping (Millikin 1988). This allows increased contact and can include all major habitat types with minimum driving time and maximum censusing time, the number of birds censused closely approaches a plot format; a fixed boundary (Emlen 1977) is needed due to the tendency to record a greater population when fewer birds are present.

Examples:

- Holmes *et al.* 1981, DeGraaf 1992.
- note: some species cannot be located with a spot or transect method (Millikin 1988).

4. Capture/Recapture

- capture/recapture can be used for non-breeding or non-stationary birds, to determine population structure and movement of individuals between habitat fragments, or to follow populations over a number of years.
- capture with mistnets, at the nest for cavity nesters or with baited traps (hawks, owls).

Type of data:

- age, sex, breeding condition, population structure (proportion of breeding: non-breeding, number of young/breeding pair), reproductive success (number of young reaching independence).
- supplement this with visual searches for fledged young.

Concerns:

- labour intensive.
- difficulty in old growth forests.
- high natural mortality rate of songbirds so low return rate.
- lack of long term baseline studies with which to compare population fluctuations.

A central banding station should be established in B.C. to monitor regional changes populations.

5. Breeding Bird Survey

A means of indicating long-term population trends.

6. Radiotag

Another means to supplement censuses; again labour intensive but important for determining movement and habitat use.

Example:

- CWS (murrelets)- early morning detections & capture with mistnets to determine movement at sea and nesting location.

Concerns:

- back-mounted radios have decreased survival of female spotted owls and their frequency of nesting; recommendation is to glue the radio to the feathers. For passerines, glue a layer of chiffon to the feathers which is attached to the underside of the transmitter.

CONCLUSION

"The biodiversity concern is not about local diversity of flora and fauna but whether species or ecosystems are threatened"

- McMinn.

A biodiversity program should include:

1. Species most likely at risk (eg. forest interior, habitat specialists);
2. Birds associated with decreasing forest communities (eg. minimum size fragments allowing movement);
3. Movement of birds across communities.

This suggests the optimum approach would be to combine a monitoring type study to determine what communities are there, with a detailed experiment on selected species to understand the processes important to biodiversity.

The detailed experiments should include population studies of reproductive success, movement in & out of habitat patches over landscape, perhaps even studies on parentage. Again from my pesticide experience:

1. Indirect effects of habitat change may not be manifested for a number of years, therefore long term studies are needed;
2. Counting techniques may not be sensitive enough to detect response to management of habitat, only studies of indirect effects will elucidate processes involved.;
3. Availability of habitat is key to biodiversity.

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SAMPLING AMPHIBIANS AND REPTILES

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Because amphibians and reptiles are generally small, secretive and inconspicuous, they are often thought to be relatively unimportant. However, they are good bioindicators of the health of an ecosystem, and their biomass can exceed that of other vertebrates in the same area. Unfortunately, there have recently been numerous declines and extinctions of amphibian and reptile populations in many parts of the world, primarily as the result human activities that alter, pollute, or destroy critical habitats.

In B.C. there are relatively few species of reptiles and amphibians, but they are tremendously diverse in terms of morphology, life history, ecology and behaviour. Because of this diversity, different species within an area may require different sampling methods.

Biodiversity means several different things, and important variation that is worth preserving occurs at several levels. Plans for preservation of biodiversity rarely consider variation between populations of a species, but ecologically, such variation may exceed that between related species. Also, because species often occur in metapopulations, with source and sink subpopulations, only preserving the habitats that have high biodiversity may not preserve the critical habitats for many species. Thus, preserving an area with many species, may or may not preserve those species.

The number of individuals and the particular species one finds on random searches depends on a variety of physical, temporal, biological, and other factors. Sampling methods include call indices (frogs), pitfall and funnel traps, and nocturnal road cruising. Special methods for sampling amphibians in streams have been developed. Standard methods for determining terrestrial salamander abundance include mark-and-recapture, time-constrained searches, surveys of coarse woody debris, and pitfall traps. However, the ecology of these organisms suggests that serious errors may arise if these methods are used uncritically. The use of artificial cover objects can be used for long-term monitoring studies and relative measures of abundance across sites.

Determination of the abundance of amphibians and reptiles is important with respect to understanding their ecology and is critical for conservation efforts. However, naive application of sampling methods without knowledge of the organisms natural history will likely produce spurious results. Management decisions should not be based on simple or superficial measures of biodiversity, but instead on detailed knowledge of the species' ecology and behaviour, and this can only be obtained by intensive in-depth studies of local populations.

SAMPLING TECHNIQUE REFERENCES

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ELEMENTS OF STUDY DESIGN

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1. Statistics cannot rescue a badly designed study.

Statistical methods or mathematical/computer wizardry cannot fix fundamental flaws in a study.

e.g. MISCONCEPTION: If ANOVA is not an appropriate statistical method (because of assumption violations, such as lack of replication) then it is okay to use t-tests even if multiple t-tests are required.

TRUTH: t-tests and ANOVA have the same basic assumption requirements (see BI# 27)[1]. Using t-tests, especially multiple t-tests, may make the situation even worse.

e.g. MISCONCEPTION: That non-parametric tests are somehow appropriate if the study has not been properly randomized etc.

TRUTH: Non-parametric tests were originally designed as 'quick' tests (before the days of computers) and are appropriate for badly non-normal data, but they still can't magically fix a badly designed study.

Suggestions:

i) Think carefully about your objectives. Describe or draw pictures of treatment responses you might expect including the possibility of no response to treatments (H_o, the null hypothesis). Do a power analysis (see below);

ii) Consult a statistician regarding the design and analysis possibilities;

iii) Consult your colleagues regarding the biology and methodology problems you have might have in implementing your study;

iv) Classify your study:
   a) experiment
   b) sample survey - must include randomness in the design
   c) observational study - many biodiversity studies in this catagory, they are valid but can be dangerous statistically

2. Power analysis

Can be used to:

i) a priori - Determine appropriate sample sizes before conducting a study;

ii) a posteriori - Determine the ability of a study to have detected practically important differences.

Type I (α) and Type II (β) errors:

α = probability of rejecting H_o when it is, in fact, true.

$1-\beta$ = power = probability of rejecting H_o when it is, in fact, false.

When we ignore β we implicitly assume that the cost of the Type II error is much smaller than the cost of the Type I error. Often, though, the reverse is true and we are not controlling the most important error rate.

It is not justifiable to accept H_o if a power calculation has not been done. Peterman's paper (1990b) is particularly relevant reading as to why power analysis is so important to do.

[1] BI stands for Biometrics Information, this is information available through the Biometrics Section, Forest Science Research Branch, B.C. Ministry of Forests.

3. Matching the analysis to the design.

The pattern of data collection leads directly to the design/layout. Together with the type of response variable and statistical model, these define the appropriate methods of analysis.

e.g. Studies that are designed in a logical and sensible manner may end up with a complicated design such as a split-split plot. Since the design seems so obvious, the complicated nature of the design may be missed by the researcher leading him/her to use incorrect analytical methods.

e.g. Most Forestry trials subsample the experimental units (e.u.'s). Often the e.u. variability is not properly separated from the s.u. variability and thus an incorrect error term is used for F-tests in the ANOVA.

RESPONSE Variable Type	Analytical Methods
Continuous:	General Linear Models (GLM) such as:
e.g. tree height biomass	- simple and multiple Regression - ANOVA - ANCOVA and comparing regression lines
Categorical:	Logistic Regression Models
e.g. dead/live condition code	Contingency tables for simple designs Log-linear models for more complicated designs (contingency tables are a simple type of log-linear model)

Traditional non-parametric statistics are available for simple designs/layouts. Since most designs I see are more complicated than this, I rarely use non-parametric methods.

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4. Important elements of study design are:

i) Replication - what are the e.u.'s/primary sampling units (p.s.u.'s)? - beware of pseudo-replication! (see BI #5)
   - *Purpose:* to obtain some idea of "natural" variability;

ii) Random selection of e.u.'s/p.s.u.'s - selected from what population?
   - *Purpose:* to obtain a sample that effectively "mirrors" the target population, so that inference to the target population is reasonable;

iii) Random assignment of treatments to e.u.'s/p.s.u's. (see BI #17)
   - *Purpose:* to assure an unbiased (on average) assignment of e.u.'s to treatments so that any differences observed between treatments are only due to the treatment;

iv) Dealing with extraneous variables:
   a) randomization;
   b) blocking/stratification;
   c) confounding - desirable and undesirable;
   d) covariance;

v) Controls - including one or more controls as a treatment level in the study may be important so that, for instance, changes in time can be separated from treatment effects.

ADDITIONAL READING

(Note that the following references are ones that I am familiar with and this is not an exhaustive list.)

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Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall Inc., Englewood Cliffs, N.J. (This book summarizes how to do many different statistical tests).

General Discussion of Study Design

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Simple and Multiple Regression

Weisberg, S. 1980. Applied linear regression. John Wiley and Sons, New York, N.Y.

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Logistic Regression

Hosmer, D.W. and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons. New York, N.Y.

Bergerud, W.A. Draft BI Handbook. Logistic regression methods used in forestry.

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Everitt, B.S. 1977. The analysis of contingency tables. Chapman and Hall, London, Great Britain.

Fienberg, S.E. 1981. The analysis of cross-classified categorical data. 2nd ed. The MIT Press, Cambridge, Mass.

Freeman, H. 1987. Applied categorical data analysis. Marcel Dekker, Inc., New York.

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Power Analysis

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* particularly relevant reading

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Seber, G.A.F. 1982. Estimation of animal abundance and related parameters, 2nd ed. Hafner, New York.

Biometrics Information (BI) Pamphlets of General Interest

2 The Importance of Replication in Analysis of Variance.

5 Understanding Replication and Pseudoreplication.

14 ANOVA: Factorial designs with a separate control.

17 What is the Design: (note that this discusses experimental design).

18 Multiple regression: Selecting the best subset.

21 What are Degrees of Freedom?

25 ANOVA: The Mean Within Sums of Squares as an Average Variance.

27 When the t-test and F-test are equivalent.

28 Simple regression with replication: testing for lack of fit.

30 Interpretation of probability p-values.

31 ANCOVA: The Linear Models behind the F-tests.

34 When are blocks pseudo-replicates?

36 Contingency Tables and Log-linear Models.

Other Biometrics Section Publications
Published Handbooks

Bergerud, W.A. 1991. Pictures of linear models.

Nemec, A.F.L. 1991. Power analysis handbook for the design and analysis of forestry trials.

Nemec, A.F.L. (in press). Guidelines for the statistical analysis of forest vegetation management data.

Poulin-Costello, M. (in press). Catalog of curves for non-linear curve-fitting.

Draft Handbooks currently available

Logistic regression methods: with some forestry examples.

Fitting the Logistic and Gompertx curves to cumulative germination data.

Workbooks or Notes

Power analysis workshop notes. 1992.

Introduction to SAS/PC. 3 volumes. Last edition prepared in Jan. 1992.